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FIRE TESTS OF TWO REMOTE AREA FIRE SUPPRESSION SYSTEM CONCEPTS

Contract NBy 62167

An Investigation Conducted At

Factory Mutual Research Corporation

Norwood, Massachusetts

November 29, 1965

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

LABORATORY REPORT

FINAL REPORT

FIRE TESTS OF TWO REMOTE

AREA FIRE SUPPRESSION

SYSTEM CONCEPTS

for

U.S. NAVAL CIVIL ENGINEERING LABORATORY

PORT HUENEME, CALIFORNIA

U.S. NAVY CONTRACT NO. NBy-62167

SERIAL NO. 15974.1

NOVEMBER 29, 1965

FACTORY MUTUAL RESEARCH CORPORATION

1151 BOSTON-PROVIDENCE TURNPIKE, NORWOOD, MASS. 02062

ABSTRACT

Two packaged, self-contained fire suppression systems were fire tested to determine which would best meet the remote area fire protection needs. Results of 31 tests indicate that the multi-cycle, total flooding system using Bromotrifluoromethane is superior to the automated sprinkler system using water.

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I INTRODUCTION

This report presents the results of thirty token tests of two fire suppression concepts which were recommended to the Navy as part of a preceding contract (FMRC 15974 NBy-32287).

The purpose of these tests as stated in the basic contract was to evaluate under fire conditions the following:

I The system flow and operating characteristics.

II The suppressant and its flow characteristics.

III The reliability and effectiveness of system components.

IV The reliability and effectiveness of the over-all system.

The effectiveness during this test program was measured by relative effect on reproducible Class A fires. Other types of fires are, however, included in considerations of total system utility.

The primary objective of the work was to compare the concepts or methods of fire suppression rather than combinations of specific hardware items. Contract Change B was issued therefore to allow flexibility. Due to the expensiveness of presently available supplies of bromotrifluoromethane it was agreed that part of the tests of this agent could be run in a smaller (180 cu ft) chamber than the 18.7 ft x 20 ft x 17.5 ft high test area in which the remainder of the tests were run. In addition it was agreed that equipment on which sufficient information already exists could be simulated and evaluated without actual testing. For instance, existing test station water supplies were used rather than purchasing a pressure tank and nitrogen cylinders. Electrically operated solenoid valves were used during testing so that multiple tests could be run from a large cylinder. Explosive actuated valves recommended for an installed system would be of a type similar to those listed and approved for carbon dioxide systems.

The problem as presented to us is the need for a packaged, self contained system, of a modular nature, for structural fire protection in remote areas where an adequate water supply is not available. The maximum building size under consideration is 40 ft x 100 ft x 20 ft high.

Since response by fire fighters is not assumed, the system must be capable of either completely extinguishing a fire of any type or of holding it in check for an indefinite period.

The water supplies normally recommended for sprinkler systems would result in excessively bulky and heavy storage. To provide the necessary amount of fail safe control equipment for individual or small groups of nozzles in order to localize and optimize agent delivery would not be feasible due to the complexity of installation and the amount of equipment needed. The further need for provision of anti-freeze agents for low temperature application increases the complexity of system design. Furthermore, if the total minimum quantity of water chosen is insufficient, the opportunity exists for a damaging fire situation. In addition the water (or water-lithium chloride solution) may not completely extinguish Class B & C fires and may in fact itself cause damage, particularly in electrical and electronic equipment.

The system using bromotrifluoromethane applied in an effective concentration (3 to 5% by volume) throughout the protected volume is comparatively simple, requires no extensive piping, no anti-freeze agent, a minimum of control equipment and will maintain its effectiveness as long as the building is kept closed and tightly sealed. In addition to an ability to reach shielded areas and extinguish or suppress Class A fires the literature suggests that it is also effective against Class B & C fires. Due to its high dielectric strength a minimum of damage to electrical and electronic equipment would be expected.

Toxicity problems were evaluated from literature sources which adequately describe the general situation (References, Section A). A more detailed experimental evaluation would be quite costly and is not warranted by the technical and financial scope of the present contract.

Briefly, decomposition of the agent during fire suppression may in some cases (large fires in small rooms) create a toxicity problem. Fires will themselves create toxic combustion products, however. Water suppressed fires are also capable of producing toxic atmospheres, particularly if the fire is shielded. If lithium chloride anti-freeze agent is added this may be decomposed. The bromotrifluoromethane is relatively nontoxic in the undecomposed state and it is expected that fires will be suppressed, in many cases, before much of the agent is decomposed. In the case of small spaces and rapidly developing fires, the toxicity (and corrosion) problem may be serious. Where personnel must ride out the emergency it is suggested that a smoke or combustion gas type detector be used to actuate the system. Where personnel must be evacuated a gas or smoke detector (not connected to the system) could be used to sound the warning, allow evacuation and allow manual fire suppression while still having the somewhat less sensitive thermally actuated fixed system for back up protection. In either case, where personnel are present, protective clothing and self contained breathing apparatus should be provided.

On the basis of the thirty tests and study of the specific application requirements (particularly in Arctic locations), the system for total flooding with bromotrifluoromethane has been recommended for additional testing and development. This system concept is considered to have the greater potential for meeting the need for remote area fire protection.

Schematic plans and generalized specifications for protecting a 40 ft x 100 ft x 20 ft building with this system are included in the Appendix.

While the concept of an automated sprinkler system using water is not being recommended at this time, for some applications it has considerable potential. For buildings which cannot be completely closed it is the only applicable choice. With additional optimization the concept could be quite effective and additional development is recommended.

II TEST METHOD

A General

The thirty tests were designed to provide an indication of the action to be expected under a variety of conditions. The series is therefore somewhat exploratory in nature in that a number of the variables involved have been allowed to change. The test results should therefore be viewed as indicating possibilities rather than patterns. Optimization of either system and a complete description of their action would require a more extensive series of tests in which independent variables are each held under more strict control.

B Test Conditions

1. Large Scale Tests

a. Building. The 18.7 ft x 30 ft x 17.5 ft brick building designated as No. 4 at the Norwood Test Station was modified by erection of a full height partition wall of two layers of one-half inch gypsum board on 2 x 4 studs to provide a test area 18.7 ft x 20 ft x 17.5 ft. The ceiling is essentially flat and of noncombustible material. A sketch showing doors and vents and general test arrangement is included in the Appendix. The room was closed for both $CBrF_3$ tests. Both open and closed room tests were run on the water system.

b. Fire. The fire event was provided by a single stack of ten hardwood (oak and maple) pallets on the floor in the center of the room. The over-all pile dimensions were 4 ft x 4 ft x 56 in. high. Initial weight of the pile varied from 727 to 761 lb. Ignition was achieved by thrusting two match lit standard igniters (1/2 pint of gasoline in a 2 ounce, 6 in. long, 3 in. diameter cotton roll fastened to a wood handle and covered with a polyethylene bag to retain the gasoline) into the bottom of the stack.

The moisture of the stacks was measured prior to each test and during the suppression series varied from 5.8 to 7.9%.

Supplementary observations were made during the $CBrF_3$ tests by inserting standard igniters fastened to a pole, and dry igniter wads ignited by an external flame from one ounce of gasoline in a container beneath the wad. These were fastened at different levels to detect inferentially if any vertical gradient of agent concentration existed. These also simulated the deep seated type of fire in a cellular material against which the gaseous agent might be expected to be least effective.

c. Protective Equipment

(1) $CBrF_3$ Test. A 150 lb cylinder of bromotrifluoromethane (Freon 1301) was mounted on a platform scale set to balance when the selected quantity of gas had been discharged. Discharge was controlled by an electrically operated solenoid. The gas was ejected through a nozzle having eight 1/8 in. jets - four horizontal, equally spaced at 90°, and four vertical. Fire detection and system actuation was provided by an open circuit strut and tube device of 140°F rating. (Fenwal Detect-A-Fire, Model 27120-19)

(2) Water System. A sketch in the Appendix shows the piping arrangement. Water was supplied to the system through a direct loaded diaphragm type valve with pilot solenoid connected to the power supply through the normally-closed-circuit, struc and tube detector (140°F) and an electrical timing circuit. Water supply to the upper chamber of the control valve is through an orifice of diameter considerably smaller than the outlet of the pilot solenoid. Fire activation of the detector opens the solenoid which in turn opens the control valve. When

the detector cools and recloses the circuit the timer starts, to give an additional five minutes (or other selected time) of water flow. At the end of this time the pilot solenoid valve closes and pressure builds up through the by-pass orifice (about 15 sec at 115 psi) to close the main valve. Should the detector again sense fire the cycle will repeat.

d. Instrumentation

(1) Temperature. Temperatures were measured by means of bare head 20 gauge chromel-alumel thermocouples adjacent to the fire detector (center), near a sprinkler link (7.1 ft from center) and at the center of the pallet stack.

(2) Water Flow. Water flows were computed on the basis of pressure at the sprinklers and by measurement with an orifice plate and differential pressure type flow meter. The flow meter was calibrated by means of timed flows into a weighing tank.

(3) Water Pressure. Pressure on the sprinkler system was measured by a bourdon type gauge connected to a 1/4 in. gauge line from a tap in the end of one branch line. It was necessary to insert a pressure snubber in the line due to water hammer introduced by the rapid opening of the flow control valve. Inrush pressures in excess of 200 psi were indicated prior to installation of the snubber. Pressures at the inlet and outlet of the flow control valve were also measured with bourdon type gauges.

(4) Gas Pressure ($CBrF_3$). Measured by bourdon type gauge located upstream of the control solenoid on the discharge line from the cylinder.

(5) Gas Flow ($CBrF_3$). Total flow was measured by cylinder weight loss. Instantaneous flow can be estimated by comparing with the time-pressure record (Appendix C-9).

(6) Gas Analysis. Samples of the room atmosphere were taken for selected tests (Water 4, 5, 6, 11 and $CBrF_3$ 9) to give an estimate of the oxygen available for combustion and potential toxicity due to carbon monoxide production. The samples were withdrawn over water in 300 ml bottles and analyzed by the Orsat method. The sampling point is shown in the sketch of the test setup. The sample probe was filled with water prior to start of the test. Samples were generally withdrawn at the time agent was applied or shortly thereafter to indicate whether the fire was being suppressed by the agent or the suffocating effects of the enclosure. This was a confirmatory observation since comparison of suppression results with free burn tests show that considerably less fuel is consumed in the suppressed fires.

(7) Fuel Weight Loss. The fuel stack was weighed prior to each test and several days after each test - after the fuel had a chance to return to nearly its original moisture content. Two single beam platform scales were used for the purpose. The weights recorded both before and after

include a tare weight (wood spacing blocks) of 1.75 lbs. Igniters are not included in the weight measurement.

2. Small Scale Tests ($CBrF_3$ Only)

a. Chamber. The small scale tests of the bromotrifluoromethane system were conducted in a noncombustible chamber 46-1/4 in. by 95-1/4 in. by 69-7/8 in. high. The volume including window depressions, etc. was about 178.6 cu ft. Ventilation was controlled by throttling the air flow at the top of the box. Suction was provided by means of a squirrel cage fan mounted at the outlet of the duct. A ventilation range of 0 to 70 cu ft per minute was possible. The inlet and outlet arrangement is shown on the sketch of the test setup (Appendix A). A small fan was installed inside the box during several of the tests to obtain a more uniform air-agent mixture throughout the chamber.

b. Fire(s). The arrangement of fuel used in most of these small scale tests is shown in Appendix A. Two pounds of wood sticks, whose dimensions are roughly 1-1/2 in. by 1-3/4 in. by 8 in. long, were arranged in a crib and ignited by 4 ounces of crumpled paper towel. Ignition of the paper was done by hand with a single flaming towel. Tests Nos. 1 and 2 are freeburn fires for comparison. The agent's effectiveness was then determined by comparing fuel weight loss and fire intensity (temperatures). The fires were positioned in two vertical locations in the center of the box to determine if a vertical gradient of agent concentration was present. In the first case

(Tests 2 through 8) the top of the crib of wood sticks was 14-1/4 in. above the floor. In the second case (Tests 11 through 14) bricks were placed under the wire basket so that the top of the crib was 32 in. above the floor.

A second fire arrangement using two cotton wads weighing 3 to 4 ounces total (each 6 in. long x 3 in. dia.) as a fuel was devised to simulate a deep-seated, smouldering fire in cellulosic material. The two wads replaced the wood crib on top of the basket of paper towels. Ignition was done in the same manner as the other fires. Fires of this nature, in our opinion, represent the most serious challenge to a gaseous agent from the standpoint of complete extinguishment.

c. Protective Equipment.

A 150 lb cylinder of $CBrF_3$ was mounted in the inverted position on a scale. The flow of gas through 1/2 O.D. copper tubing in pounds was determined to the nearest quarter pound. Discharge was controlled manually by tripping an electrically operated solenoid valve. The gas was injected through a 3/32 in. diameter orifice located just below the top of the box. Fire was detected in all tests by means of a tube and strut heat detector mounted at the top of the box, directly over the fire. Its temperature rating was 140°F. Test No. 3 was the only test in which the system was activated at this signal, however.

d. Instrumentation

(1) Temperature. Temperatures were measured by means of three bare bead, 20 gauge, chromel-alumel thermocouples

located at the ceiling directly over the fire, at the ceiling near the right front corner of the box and at the center of the crib. For the cotton wad fires a thermocouple was placed between the two wads.

(2) Gas Pressure ($CBrF_3$). Measured by bourdon gauge located upstream of the control solenoid valve on the discharge line from the cylinder.

(3) Gas Flow. Flow was measured by cylinder weight loss. The scale provided continuous readings which indicated a steady flow for the small amounts of gas discharged.

(4) Oxygen Analysis. Continuous samples of chamber atmosphere at the rate of 1 cfm were taken and evaluated for oxygen content by means of an oxygen analyzer. The purpose was to determine whether the fires were extinguished due to the shortage of oxygen or by the action of $CBrF_3$. This method will be discussed in more detail in the section on Test Results.

(5) Acid Build-Up. A thin film of distilled water (PH of 7.0) with a surface area of 90 sq in. was located on the floor near the base of the fire. Hydrogen ion concentration (PH) readings were made with an electronic PH meter. Litmus paper was used to check the results.

Indicator papers with a 1 to 6 PH range were exposed to the atmosphere produced by many of the small scale fire events. These were located at various heights in the box and were visible during the tests.

(6) Fuel Weight Loss. The individual weights of paper, wood and cotton were recorded prior to each fire. Since each fire was actually a composite of either wood and paper or cotton and paper, the total weights were also recorded. After completion of all tests the composite and individual weights were immediately measured. In the case of the cotton wad fires (Tests #17, 18 and 19) continuous readings were taken during the fire.

III TEST RESULTS & DISCUSSION

A Water System

A normal sprinkler system is generally designed with water supplies sufficient to control a fire for an extended period of time. For example, the requirement for a low demand occupancy can be as much as 500 gpm (15-20, 1/2 in. sprinklers) for 1/2 to 1 hour duration (Ref. - FM Handbook of Industrial Loss Prevention, page 12-3). This quantity is hoped to be sufficient to keep the fire under control and reduce its intensity and spread until final extinguishment (mopping up) can be accomplished by the intermittant use of hose streams. Hopefully the sprinklers will completely extinguish the fire (and in many cases they do - often with fewer than five sprinklers), but generally it is assumed that the coup de grace can be applied, if necessary, by trained fire fighters.

In the case of a self-contained, portable system for advanced bases, response by trained fire fighters cannot be assumed. Since the water will not persist in an effective form, the problem is to determine the optimum method of application and minimum quantity which will reliably and completely extinguish all fires considered possible.

As yet there are few quantitative data upon which to predict the optimum form of a spray (drop size distribution, cone angle, velocity) for any but a few limited fire situations (fuel type and arrangement and building size and geometry). If the optimum balance can be found there is still the question of whether it is more efficient to apply a large quantity of water (or LiCL - Water Solution) in a short time (seconds) or a smaller quantity in a longer time (minutes-hours). The figures would, of course, be different for each size and type fire (e.g. the fire intensity and geometry at the time of detection and agent application) and the consequent area of burning surface to be extinguished. Dependent variables, such as the number of sprinklers (of a given type) to operate must also be defined for each set of independently controlled variables or system design parameters.

These tests were all conducted at prevailing temperatures of 75 to 90°F and with city water to which nothing was added. Reynolds Number correlations have indicated that a friction loss three to four times that of water can be expected when flowing a lithium chloride-water solution (24% by weight, kinematic viscosity 71 centistokes at -65°F) through a four sprinkler system with 2 in. pipe at -65°F. This solution at -65°F has about the same characteristics as an SAE 30 mineral oil at +150°F. A more extensive program than is called for in the present contract is needed to delineate the changes in system design necessary to compensate for variation in viscosity and density with temperature. Literature mentioned in previous Contract NBy-32287 also indicated differences in the mechanisms and efficiency of extinguishment which a future project concentrating on design of a fixed water-anti-freeze system for low temperatures should investigate. Due to choice of the bromotrifluoromethane and lack of funds, investigation of these items has not been undertaken.

The data as tabulated in the Appendix show several things.

1. In Tests Nos. 10 and 11, in which a simultaneous deluge from four open sprinklers was triggered by the detector, the water was applied more than a minute sooner than would have been the case with a discharge initiated by operation of the less sensitive sprinkler links. Consequently fuel weight loss was less and ceiling temperatures lower. The possibility of extinguishment with a significantly lower consumption of water is also much better.

2. Increases in water pressure with automatic sprinklers may not always be beneficial; a high pressure at the first sprinkler may provide sufficient cooling to prevent the operation of other sprinklers. The resultant discharge onto the fire may be so unbalanced that inadequate fire control will be attained (see Test 7).

3. The choice of duration of water application is critical. If the fire is not extinguished during the first cycle there is a very real possibility that the fire may become more deep seated and consequently more difficult to extinguish. In each case where a minimum discharge time of 15 seconds was tried the consequent fuel weight loss was high, water consumption not significantly diminished and complete extinguishment was not obtained even though the water density per sprinkler during application was in one case comparatively high (see Tests 4 and 6).

4. The degree of ventilation to the room will have little effect on the efficiency of suppression except in the following cases:

a. A closed room can trap heat and cause prompter actuation of detectors.

b. If suppression is delayed the depletion of oxygen may assist in eventual suppression. Oxygen concentration measurements indicated that this was not an important factor during this test series - except in the case of the free burning fires in the closed room

c. If a fine fog is used (either by increasing pressures or choosing the proper nozzle design) the closed room may serve to confine and recirculate the air-borne particles and consequently improve the efficiency of suppression.

5. As shown by the distribution tests, sprinkler design must be considered along with the pressure to be used and location of the device with respect to the fire. Beyond a five or six foot radius there may be little or no improvement with increasing pressure. Some diminution of the water application density on the fire may actually take place.

6. Even where the pallet stacks were extinguished, the igniters were, in some cases, still flaming or smouldering at the end of thirty minutes.

In summary, it has been shown that the type of fire used in this test series can be suppressed with a limited supply of water but that complete extinguishment cannot be guaranteed. Since the agent does not persist in the fire area - except where wetting has occurred, response by fire fighting personnel is mandatory (even though they may not always be needed).

The agent control and delivery system performed reliably throughout the test series.

B. Total Flooding Bromotrifluoromethane ($CBrF_3$)

1. General

Total flooding systems using carbon dioxide as a suppressant are often used in present day industrial fire protection. These systems are most effective on surface burning materials such as flammable liquid pools and cellulosic materials in the early stages of combustion, rather than deep seated fires. In a few instances, however, they have been used to protect record and fur vaults. Both of these are classified as Class-A combustible fuels. Applications of this nature are somewhat rare and are only considered when water damage is as serious a problem as fire damage.

The major disadvantages of this type of application are (1) the concentration of carbon dioxide required is high, roughly one pound for every 6 to 8 cu ft of volume and, (2) the room to be protected must be tightly sealed. Additional gas is provided to make up for leakage.

When bromotrifluoromethane is used in place of carbon dioxide the amount of agent required is reduced significantly, since its effectiveness on fires in Class A combustible fuels is greater. The results of 17 small scale fire tests and two large scale fire tests indicate that a concentration of 3% by volume or one pound for 85 cubic feet of protected volume can be effective against most fires in Class A combustibles.

2. Small Scale Tests

Tests in this grouping fall into four additional categories, these are:

a. Freeburn (Tests 1 and 2). These were run to establish reference conditions for comparison with tests in which the fires were suppressed. During these fires there was no forced ventilation as such. About one cubic foot per minute was being withdrawn by the oxygen analyzer (catalytic combustion type) and the two 42 sq in. inlet filters were open in order to maintain a reasonable pressure equilibrium. During the period of most active combustion the amount of fresh air being drawn in is less than the one cubic foot per minute since the fire itself is supplying gas to the chamber. In both of these fires approximately two-thirds of the fuel was consumed. The indicated oxygen concentration dropped gradually to a low of about 11% by volume at 20 minutes and remained at this level until the end of the test.

b. Crib Fire - 14-1/4 in. high (Tests 3, 4, 5, 6, 8). This is the orientation shown in Appendix A. The first two of these (5 lb $CBrF_3$) produced extinguishment when the agent was applied at the time of fire detection and after a 1 min 13 sec preburn to allow the fire to become established. The amount of agent was then decreased to 3 lb in Test 5. Since extinguishment was again obtained, additional forced ventilation (40 cfm) was provided (Test 6). Extinguishment was still obtained. The oxygen concentration readings in all cases were in excess of 19% at the time of $CBrF_3$ injection. After agent injection, however, the oxygen indications were quite low (8 to 13%). When agent alone was applied in the absence of fire (Test 7) the readings were even lower than the corresponding test with fire. The device also had an excessively long (hours) recovery time after contamination with agent - even after allowing uncontaminated air to flow into the sampling tube. Mr. N. W. Hartz of the Mine Safety Appliances Co. has indicated in an article* that halogenated hydrocarbons in air are oxidized on contact with the hot wire (platinum) forming halogen acids whose salts deposit on the filament and its supports and cause significant drift in indication and relatively short filament

*Hartz, N.W. "Use of Combustible Gas Indicators" NFPA Quarterly Apr. 1959 pp 357-365.

life. It was decided therefore that the readings after injection of agent should be neglected since they were only of peripheral interest.

The fact that there was little indication (fuel weight loss) of 5 lb of agent being much more effective than 2.5 to 3 lb either with or without ventilation led to the question of whether the fire was being submerged in a layer of nearly undiluted agent. The way in which ventilating air flows in and out of the chamber could also result in a recirculating or stagnant region of the highly dense (5 times heavier than air) agent with little mixing or entertainment taking place. It was decided therefore to raise the level of the fuel in the chamber and to provide a small fan inside the chamber to supply additional mixing of the $CBrF_3$ and air. A description of these follows. It was also decided at this time to use the multiple jet discharge in the full scale (6550 cu ft) tests and to orient it so that the mixing length was greatest.

c. Crib Fire - 29 in. high (Tests 11, 12, 13, 14). These tests gave no indication of any loss in effectiveness of the agent at ventilation rates up to 40 cfm even with the amount of agent decreased to 2 lb. At higher ventilation rates the fuel weight loss showed an increase even though extinguishment was accomplished and total weight loss was only about half the loss which occurred during the freeburn tests.

d. Cotton Wad Fires (Tests 15, 16, 17, 18, 19). As mentioned previously gaseous extinguishing agents are generally least effective against deep seated, smoldering fires in cellulosic or carbonaceous materials particularly where these materials are arranged in a cellular manner with entrapped air. This configuration in effect insulates an area of hot material so that cooling below the ignition point is difficult. A complete evaluation of the manner in which $CBrF_3$ behaves against this type of fire would require a more intensive series of tests than is called for in this contract but the tests outlined here have indicated that, even though complete extinguishment may be slow, the degree of suppression is sufficient to prevent a serious fire.

The basket of paper towels was left in the same position as for the previous tests (c) but the crib of redwood stick was replaced with two cotton igniter wads each 6 in. long by 3 in. diameter and totaling three to four ounces.

A freeburn test (No. 17) was conducted in this series, to provide the reference weight loss and time temperature condition. In Tests 15 and 16 it was somewhat difficult to determine visually the relative stage and rate of combustion. The fire was allowed to burn for three minutes before injection of 2-2.5 lb of agent. At the end of each of these tests (15, 16) the wads were nearly consumed with the remaining 10% or so still smoldering. It was decided to reduce the preburn time so that there would be more material left to burn at the time of agent injection. It was also decided to mount the fuel on a scale so that a continuous weight loss record could be obtained. Due to lack of complete extinguishment in Tests 15 and 16 the amount of agent was increased to 3.5 lb.

Even with the decrease in preburn time the fires became sufficiently established in one of the two wads in each case so that even after injection of agent the two most deeply involved wads continued to smolder and be consumed.

The significant thing about these two tests is that the second wad in each case, even though at nearly the same stage of involvement, was extinguished. Continued burning of the adjacent wad failed to cause reinvolvement of the second wad even though the two were initially touching. The situation improved as the one wad continued to be consumed since its dimensions decreased and the space between the two wads became greater as the test proceeded.

This same effect might be expected to take place in a larger single mass of material (e.g. a fire in the center of a mattress). As the fire proceeds, the diameter of the area of involvement will increase and eventually the lack of heat feedback from adjacent surfaces may allow more efficient cooling. This coupled with a situation in which the agent has more access to the fire could result in eventual extinguishment. Even if fire in a single mass of material cannot be completely extinguished the fire may be suppressed sufficiently so that a serious, spreading, intense fire will be prevented. Since this cooling-extinguishing effect may take some time (minutes or days depending on the material and its geometry), the building should be kept tightly closed for the longest time possible and in any case no less than 30-60 minutes. Where the building must be opened in the minimum time it is suggested that, personnel be provided with self contained breathing apparatus and trained in the use of radiometric devices and proper portable extinguishing equipment to assure final and complete extinguishment prior to venting the building.

A more intensive and definitive investigation of the degree of effectiveness in suppressing smoldering - glowing combustion should be undertaken.

2. Large Scale Fires

Tests Nos. 9 and 10 were conducted in the 6550 cubic foot test room with all vents and openings closed. The $CBrF_3$ was injected into the room at the time the 140°F heat detector operated. A multiple jet nozzle was used to improve the mixing of agent and air. The nozzle was located low in the room pointing up, for the same reason - so that the vertical jets of heavy gas would be directed at the ceiling and then fall, This effectively doubles the mixing length over that which would be available to a jet at ceiling level directed either horizontally or vertically downward.

The mixing of $CBrF_3$ and air is something of a problem due to the large amount of dilution and the large density difference. Additional investigation should be undertaken in the future to define and optimize this process, particularly if any consideration is to be given to provision of a local application (rather than total flooding) type system.

Observations on the dry and gasoline soaked igniter wads confirmed the observations noted in the preceding description of small scale wad fires.

The results of these large scale tests confirm that a 3% (when completely mixed in air) concentration of agent is effective. For the stated

20 x 20 x 20 = 8000 cubic foot module this would amount to 94 lb of $CBrF_3$. To provide a minimal safety factor this has been rounded off to a recommended 100 lb (or 3.2%). This is based on nominal building dimensions. The presence of storage and building fixtures should not be used as justification for diminishing the amount of agent required. This diminution of volume should be considered as an additional safety factor, improving initial suppression and compensating for minor unavoidable leakage.

IV CONCLUSIONS

A System Choice

The results of our token tests and an evaluation of available literature have led to the conclusion that, while both of the systems under consideration show considerable promise, the system for total flooding with bromotrifluoromethane has the better potential for meeting the need for remote area fire protection,

A comparison of potential effectiveness and reliability is the basis of this choice:

1. Effectiveness.

   a. A small or total quantity and weight of agent is required for the $CBrF_3$ system.

   b. The agent is expected to be effective against Class A, B and C fires whereas the water system would have only limited effectiveness on Class B and C.

   c. <u>As long as the building remains closed</u> the agent will persist in an effective form whereas the water system, which is local application in nature, loses much of its effectiveness when the discharge ceases.

d. The fact that response by fire fighters is not a necessity is an advantage, particularly for remote area application. The applications under consideration are all at military installations, therefore, it can be assumed that the actions of any personnel who might be present can be controlled or directed to a high degree. This is advantageous since it is necessary for the building to remain closed. Since early access to the building can never be ruled out, especially where fire control personnel are available, self contained breathing apparatus should always be provided. Also, radiometric devices would be desirable for locating the fire or hot-glowing materials in addition to the usual portable extinguishing apparatus. This would allow personnel to enter for rescue and to assure complete extinguishment prior to venting the building.

e. The application of agent upon activation of a sensitive fire (heat) detector has been shown to be considerably more effective than delayed application when relying on the less sensitive sprinkler links. An even faster system in which a more sensitive smoke or gas detector is used should receive consideration. The first shot of agent (and/or an alarm) could be controlled by the smoke or gas detection unit with back up or second shot protection controlled by the thermal sensor. This would, however, increase the system complexity somewhat.

f. The gaseous agent can penetrate to shielded areas which the liquid agent (water or water-lithium chloride solution) would not reach.

2. Reliability

a. The simplicity of the system, particularly in the amount and arrangement of equipment, is a prime reason for expecting greater functional reliability. The ability of the agent to remain in the liquid state and be self propelling over a wide temperature range is one reason for this simplicity. This simplicity also results in ease of transportation, installation and maintenance.

b. The fact that this is a total flooding system rather than local application, with consequently more predictable discharge rate and quantity characteristics, leads to an easier and more reliable estimation of total system effectiveness in fire suppression.

B Amount of Agent Required

Our token tests have indicated that one hundred pounds of $CBrF_3$ should provide adequate protection for a unit volume of building (20 x 20 x 20 = 8000 cubic feet). At a present price of approximately $3.00 per pound this would be $300, or $600 for a two shot system. A 40 ft x 100 ft x 20 ft building would require ten modules, or $6,000 in agent cost. If large tonnage production of this chemical can be achieved in the future its price may decrease to $1.00 or less per pound. The building volume occupied by storage, equipment, fixtures, etc. should be considered as insuring a somewhat higher initial concentration and a measure of allowance for leakage rather than justification for diminishing the amount of agent.

C Toxicity - Corrosion

Our evaluation of rather extensive small scale studies of bromotrifluoromethane by others (Bibliography Section A) and observations during this test series indicate that in small volumes (one or two 20 x 20 modules), with rapidly developing or well entrenched fires, toxic and corrosive combustion and agent decomposition products can be produced in serious concentrations. This is also the case to one degree or another with a water or water-lithium chloride system under the proper conditions.

During the fire tests of the $CBrF_3$ system concept acidic atmospheres were indicated by litmus paper color changes, surface etching of glass (HF) and brief sensory exposures. No other qualitative or quantitative analyses were made. Reference A-1 reports the following maximum concentrations of toxic products formed when $CBrF_3$ is applied to small test fires: hydrofluoric acid 49 ppm, hydrobromic acid 4 ppm, carbonyl halides 58 ppm and carbon monoxide 9000 ppm. All of these are above the tolerable limits noted in Reference A-9. It is yet to be determined what concentrations would be present in full scale situations with optimum detection (eg ionization type detector) and optimum suppression (eg explosive dispersal of a high concentration of $CBrF_3$).

Descriptions of test procedures used by others and consultation with representatives of the Environmental Health Laboratory at Harvard University convinced us that a definitive experimental investigation of this problem was not possible within the technical and financial scope of the present project.

Any further large scale testing should include an experimental evaluation of toxicity. This would include a complete program of gas analysis (qualitative and quantitative) for various fire environments. Additional studies of the physiological effects also seem to be warranted.

Where the fire at the time of detection is small with respect to total building volume the hazard may not be serious. With the present state of knowledge it is suggested that personnel not be expected to ride out the fire-suppression event without protective clothing and self-contained breathing apparatus. Where personnel are present and must be evacuated a smoke or gas detector could be used to actuate an alarm prior to thermal actuation of the protection system. Primary actuation of the system by a smoke or gas sensor should be considered as a solution in special situations.

V RECOMMENDATIONS

A A complete system for a single module of the bromotrifluoromethane system should be fabricated in accordance with the plans and specifications. It may be advisable to consult with specific manufacturers or distributors of equipment of the type required.

B Additional testing of suppressant action on cellular and cellulosic materials subject to deep seated smoldering glowing combustion should be conducted in single modular volume or smaller scale tests.

C The single system module should be tested in a cold environment (-65°F). This would be done to assure that fire suppression is still effective; to assure proper mechanical operation and to allow experimental evaluation of discharge characteristics.

D A complete multi (10) module system should be fabricated and tested for:

1. Proper operation and interaction of electrical and mechanical components. This should be done at both normal and extremes of temperatures.

2. Fire suppressing action at normal temperature with particular consideration being given to larger concentrations of combustibles and variations of the fuel and building geometry.

E Specific arrangements should be made for comprehensive experimental evaluation of the toxicity-corrosion hazard during the large scale tests noted above. This would include continuous gas sampling and analysis.

F A study of the mixing of $CBrF_3$ and air should be continued so that an optimum method of dispersal can be developed. This study would include an evaluation of high rate or explosive dispersal of agent so that suppression is begun with a minimum of delay. This could be done in conjunction with the study of high sensitivity fire detection (fire gas, smoke, thermal radiation sensor) for locations where these are applicable.

G The use of a smoke or combustion gas sensor or combination fire gas-thermal sensor actuation of the system should be experimentally investigated.

H A more detailed, on site, evaluation of proposed applications should be made so that comprehensive application standards can be developed.

I A separate investigation should be made of methods for providing an agent (such as water and additive) application system having independent detector actuated on-off control of individual nozzles. This would ideally be a self-contained thermal detector, valve, nozzle, power supply unit which could be "plugged" into any system consisting of fixed piping and agent container. A less ideal method would be independent automatic control of small groups (2, 3, 4) of nozzles. This is considered to be one control concept by means of which the water supply requirements for a fixed system can be significantly reduced. Collection and recirculation of agent is another. Comprehensive testing would be needed to arrive at optimum design parameters and application standards.

J The design of future remote area structures should include fire protection considerations so that a complete self contained building-protection module will be provided. This is one way that priority and logistics problems can be overcome. This concept would of course be differently applied for the various building types such as the modular aluminum and air inflatable structures now under development for the armed services.

JSS:mld

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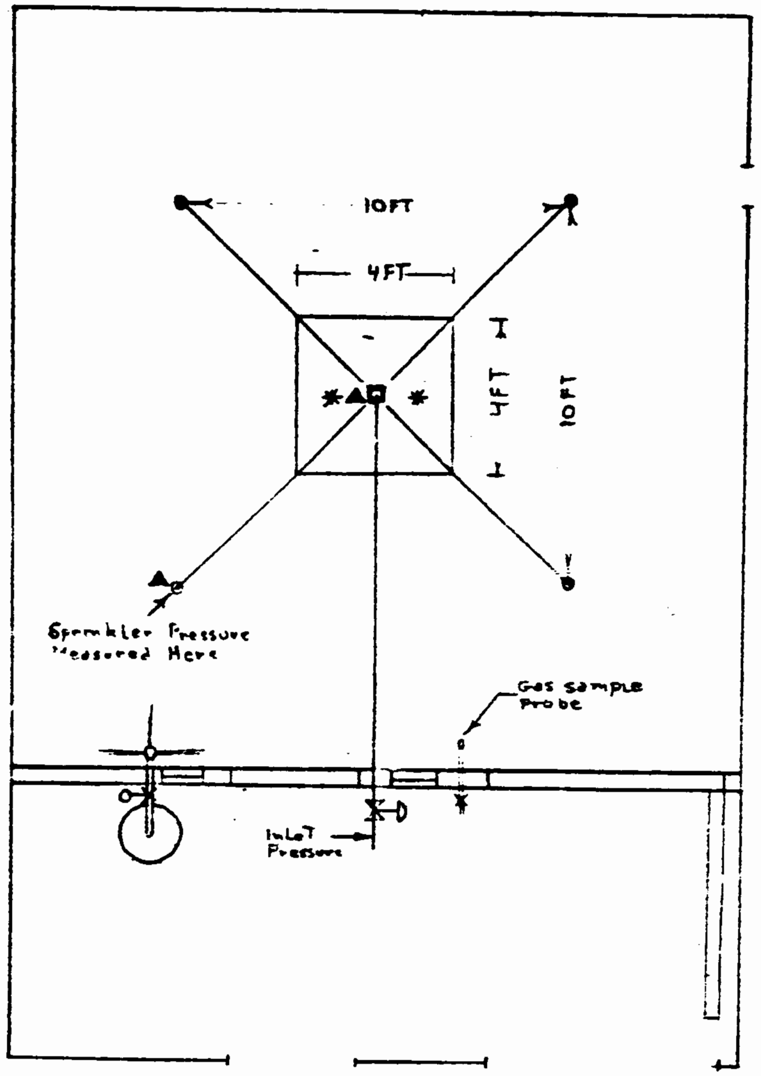
ORIGINAL DATA	:	Laboratory Notebooks Nos. 235, 236
ATTACHED	:	Appendixes A(9), B(15), C(9), D(3), E(3)

15974.1

APPENDIX A-1

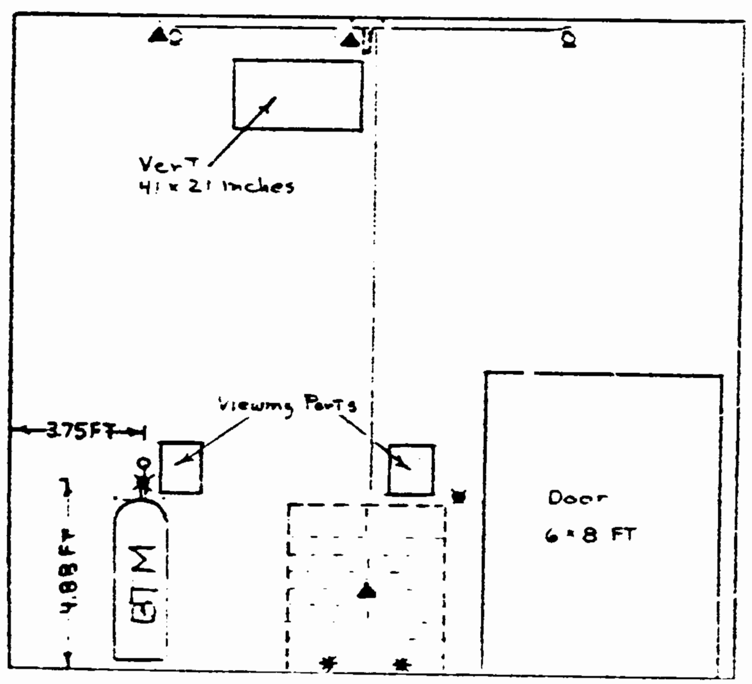
ARRANGEMENT FOR TESTS OF THE WATER AND BROMOTRIFLUOROMETHANE SYSTEM CONCEPTS IN AN 18.7 × 20FT × 17.5FT HIGH ROOM

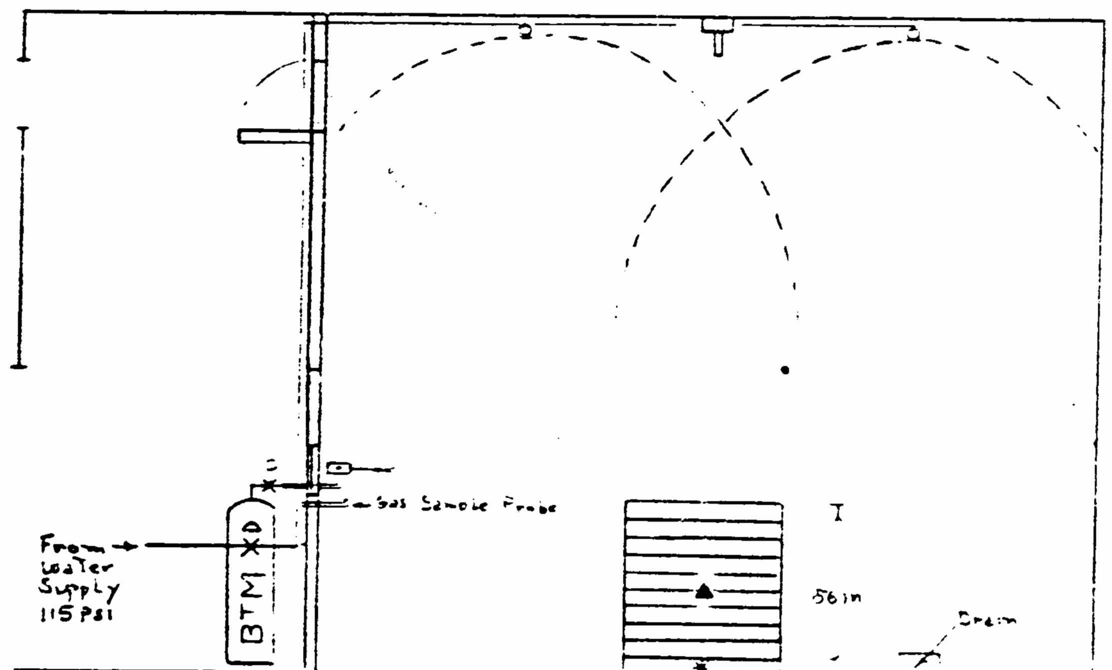


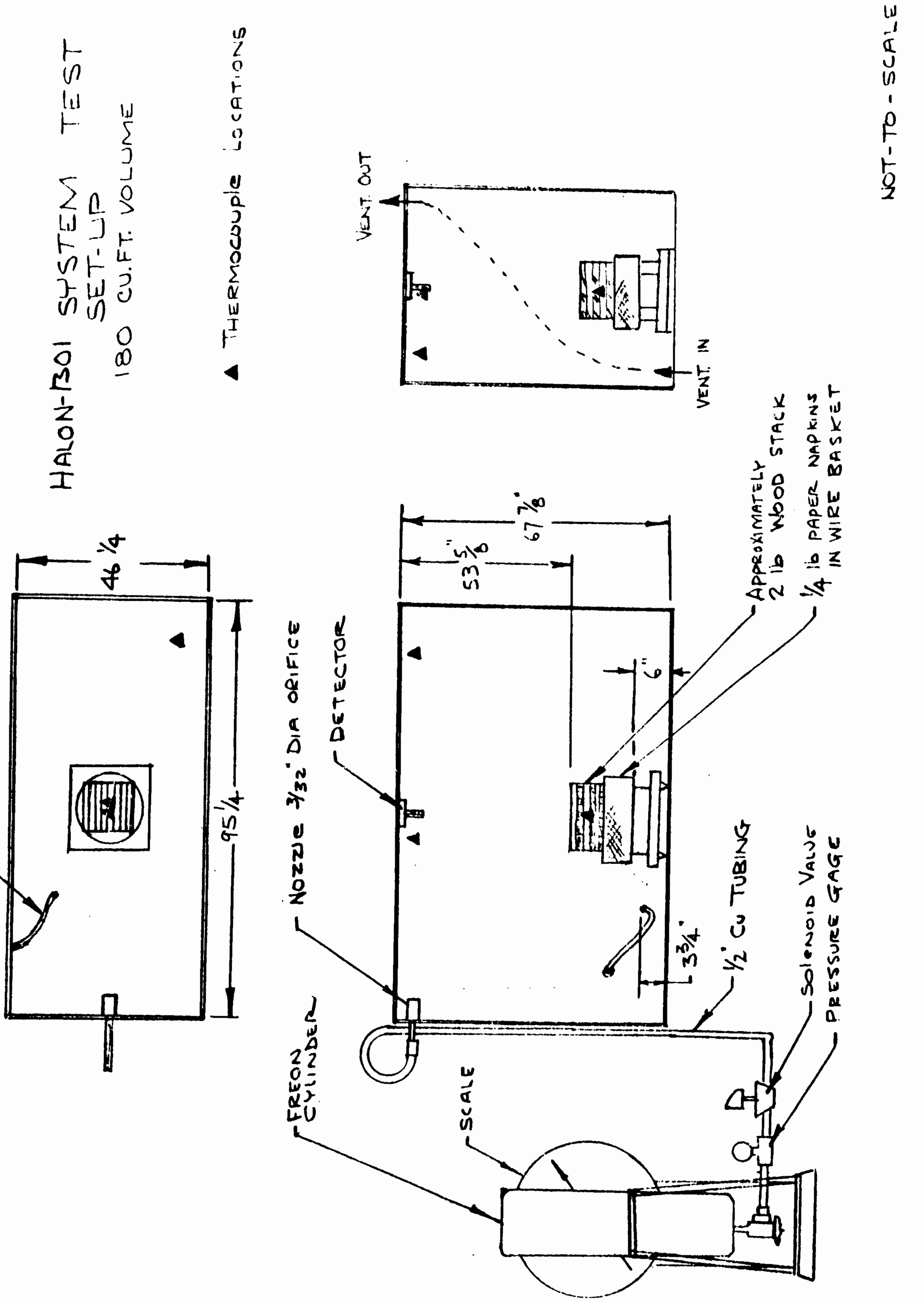
▲ Thermocouples
✱ Igniters
Fire Detector
Sprinklers

BTM Bromotrifluoromethane Cylinder

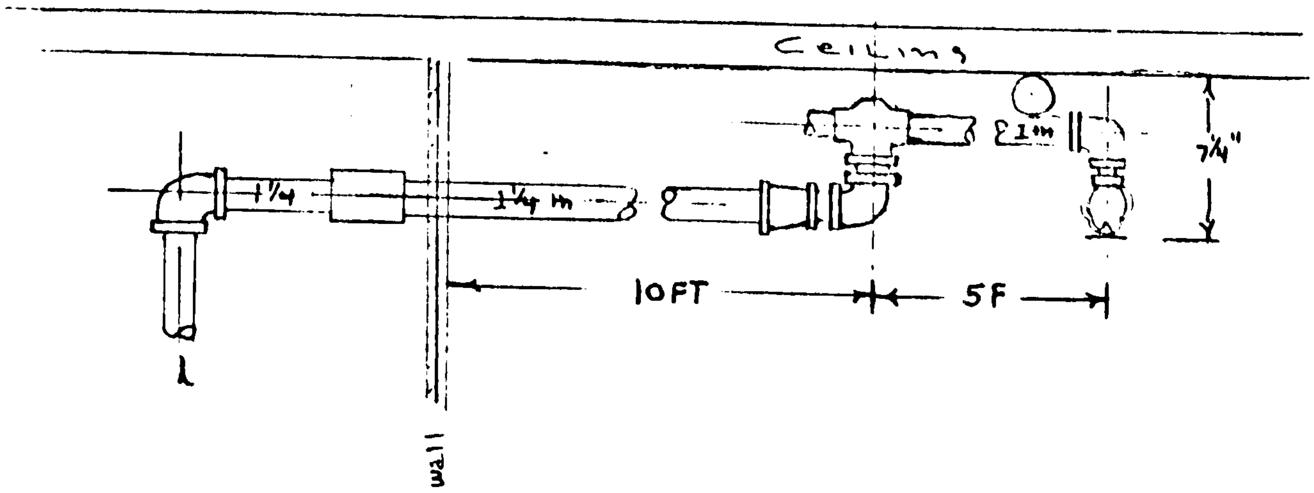
0 1 2 3 4 5 FT

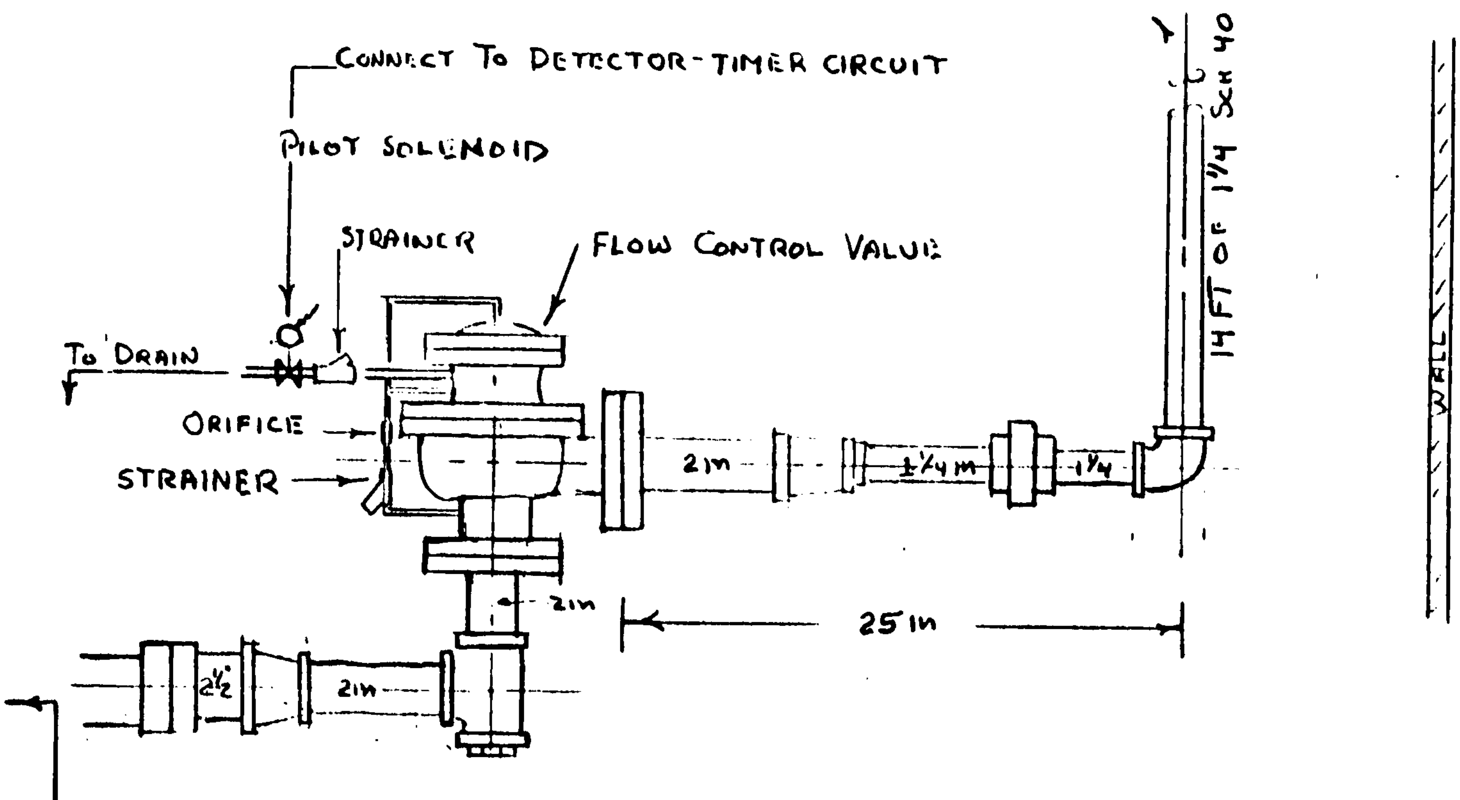





HALON-1301 SYSTEM TEST
SET-UP
180 CU.FT. VOLUME
▲ THERMOCOUPLE LOCATIONS
NOT-TO-SCALE
VENT OUT
VENT IN
46 1/4
95 1/4
ATM. SAMPLE INLET
53 5/8"
67 7/8"
6"
3 3/4"
APPROXIMATELY 2 lb WOOD STACK
1/4 lb PAPER NAPKINS IN WIRE BASKET
NOZZLE 3/32" DIA ORIFICE
DETECTOR
1/2" Cu TUBING
SOLENOID VALVE
PRESSURE GAGE
FREON CYLINDER
SCALE

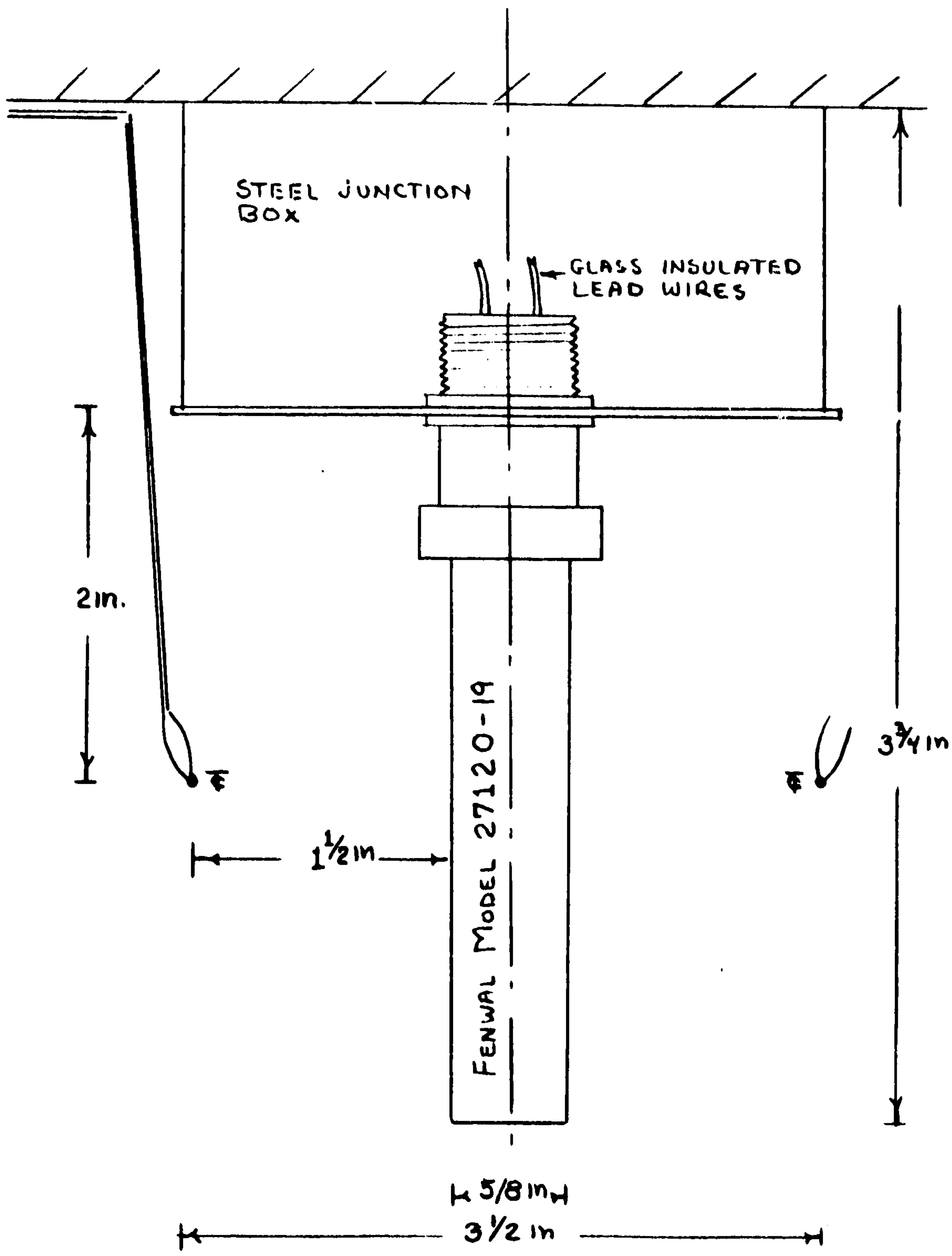
PIPING FOR WATER SYSTEM

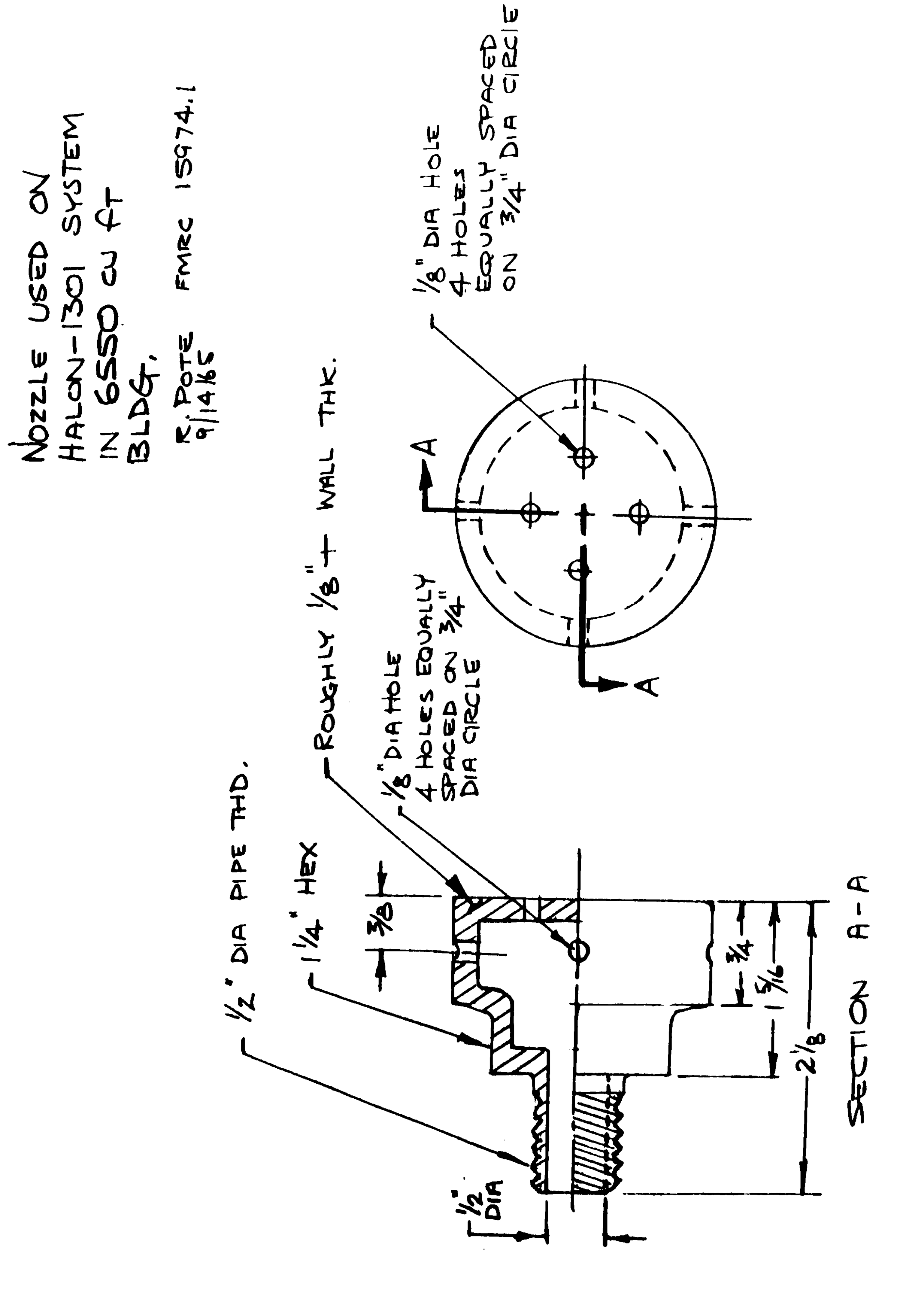




SCALE 1 in = 10 in

DETECTOR AND THERMOCOUPLE LOCATION AT THE CEILING OF THE 6550 CU. FT. FIRE TEST ROOM





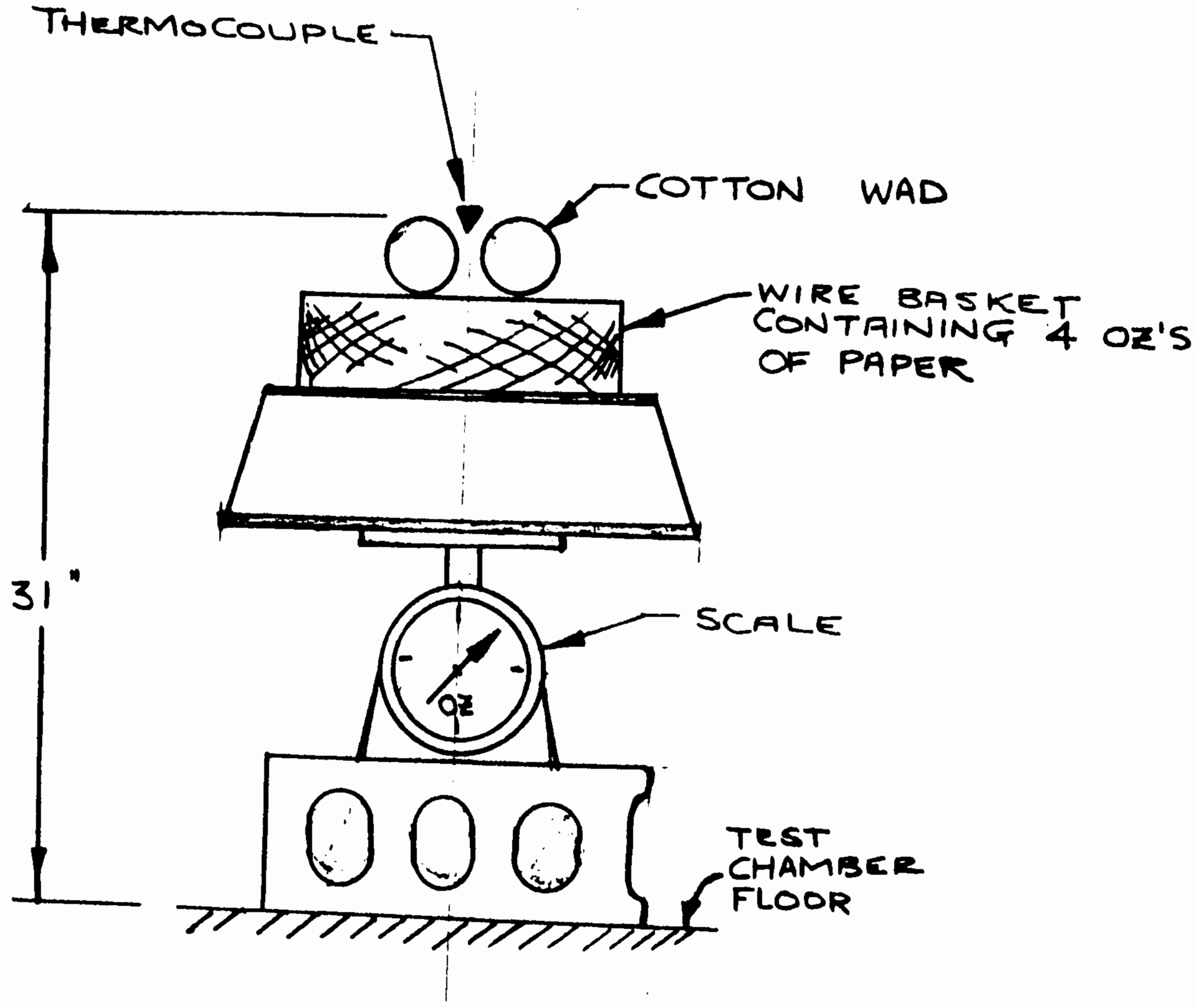
Nozzle used on Halon-1301 system in 6550 cu ft bldg.
R. Pote 9/14/65
FMRC 15974.1
1/8" dia hole 4 holes equally spaced on 3/4" dia circle
A
A
1/2" dia pipe thd.
1 1/4" hex
Roughly 1/8" + wall thk.
1/8" dia hole 4 holes equally spaced on 3/4" dia circle
3/8
3/4
1 5/16
2 1/8
1/2" dia
Section A-A

15974.1

APPENDIX A-6

HALON-1301 TEST SET-UP

COTTON WAD ARRANGEMENT



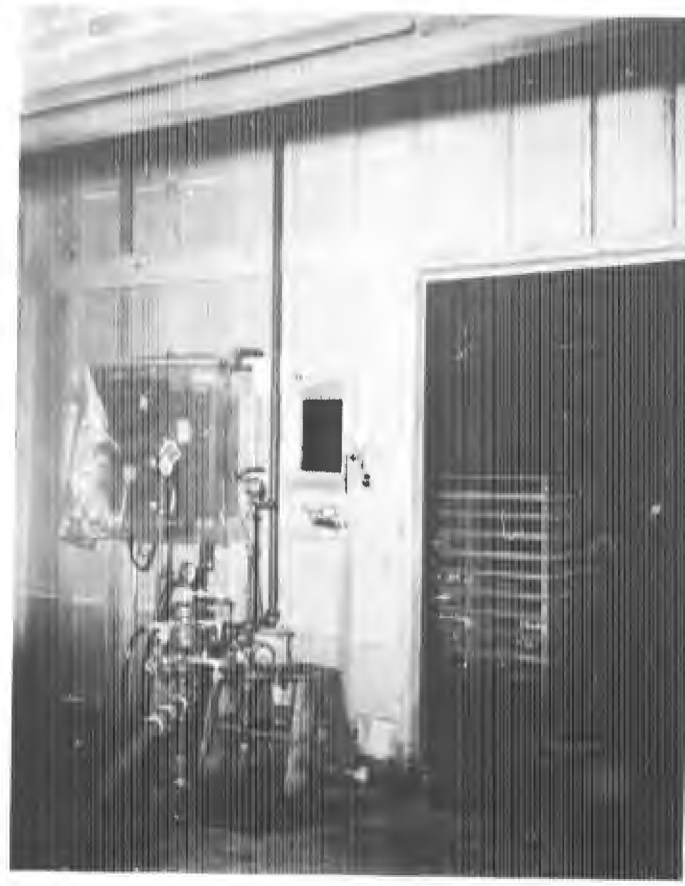
NOT-TO-SCALE

(1293-4)

Fuel and Igniters for Large Scale Fire Tests

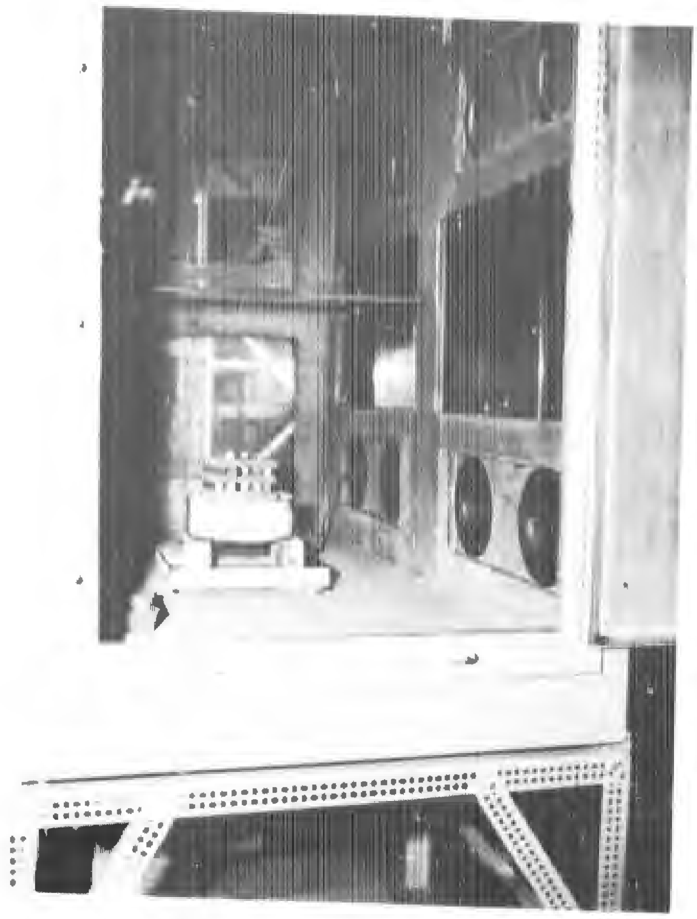
(1293-10)

Igniters for Large Scale Fire Tests



Water System Test Set-up (1293-4)

Exterior of Test Building (1293-6)



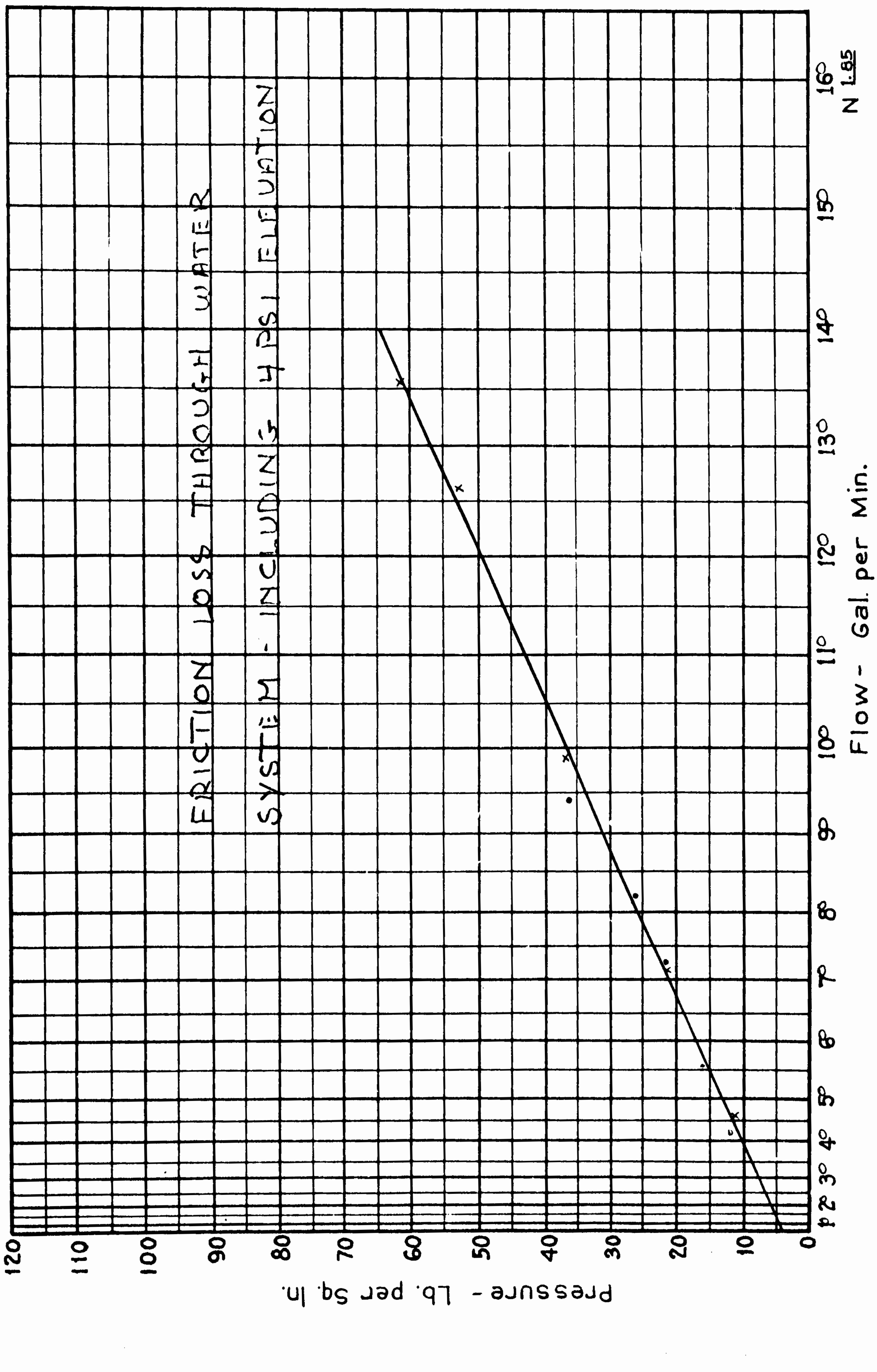
Typical Fire Set-up in Small Test Chamber (1295-7)

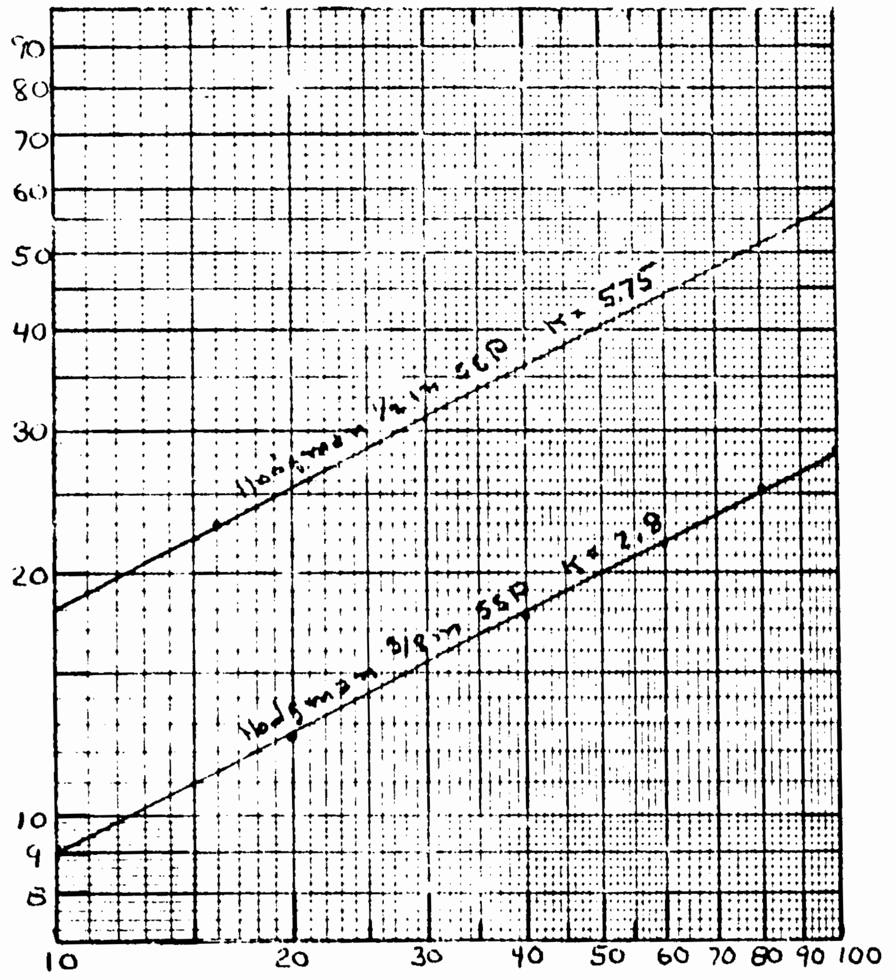
Halon-1301 Large Scale Test Set-up (1293-9)

WATER SYSTEM TEST DATA

TEST NUMBER	1	2	3	4	5	6	7	8	9	10	11	12
DATE	6-22	6-24	8-2	8-3	8-4	8-4	8-5	8-9	8-10	8-16	8-18	8-25
TEMPERATURE, HUMIDITY - %	80, 60	75, 76	83, 75	80, 75	82, 65	83, 65	80, 71	90, 76	85, 75	90, 70	82, 84	80, 70
SPRINKLER ORIFICE SIZE, IN.	NONE	NONE	1/2	3/8	3/8	1/2	1/2	1/2	1/2	3/8	3/8	3/8
VENTILATION	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	OPEN	CLOSED	OPEN
INITIAL FUEL WEIGHT - LBS	403	854	642	741	743	727	761	782	746	745	753	749
AVERAGE FUEL MOISTURE - %	12.3	16.8	7.8	7.4	7.3	7.5	7.9	6.9	7.0	7.4	6.5	7.6
DETECTION TIME - MIN-SEC.	5-10	3-15	3-15	3-00	2-13	2-10	3-00	3-30	4-50	4-10	[illegible]-12	2-30
SPRINKLER OPERATION TIME	-	-	4-30	4-10	3-35	3-15	4-15	4-40	5-50	4-10	4-12	4-00
NUMBER SPRINKLERS OPERATED	NONE	NONE	4	3	2	2	1	2	4	4	4	4
PRESSURE AT OPEN SPRINKLERS	-	-	34	90	100	75	91	56	38	68	68	68
INITIAL OFF DELAY	-	-	1-15	0-15	5-15	0-15	5-15	6-15	5-15	5-15	5-15	5-15
NUMBER OF CYCLES	-	-	1	5	1	8	6	1	2	1	1	1
TOTAL WATER DURATION	-	-	2-15	6-24	7-38	21-00	46-30	6-20	11-15	5-35	5-31	7-30
WATERFLOW PER SPRINKLER	-	-	33.5	26.7	28.0	50.0	55.0	42.0	35.5	23.5	23.5	23.5
TOTAL WATER FLOW - GPM	-	-	134	80	56	100	55	84	142	94	94	94
TOTAL WATER USED - GAL.	-	-	302	512	427	2100	2560	531	1600	525	517	705
TEST DURATION - MIN.	30	30	30	60	30	60	60	60	60	30	30	30
FUEL WEIGHT LOSS - LBS	78	82	59	37	4	34	146	6	25	<1	2	11
FUEL MOISTURE AFTER TEST	-	-	8.6	7.3	8.6	8.9	7.3	7.8	8.1	8.0	5.8	8.8
MAXIMUM CEILING TEMP. °F	800	710	730	565	500	580	510	460	420	162	167	690
TIME OVER 200°F	5-0	5-15	1-15	2-20	1-50	1-20	1-20	1-20	1-00	0	0	1-45
MAXIMUM FUEL PILE TEMP. °F	-	-	-	1660	1220	1320	740	990	790	220	220	1160
TIME FUEL OVER 200°F	-	-	-	18-20	4-40	15-00	3-30	3-20	2-30	0-15	0-15	4-00
END OF TEST STATUS - FUEL	HOSE APPLIED		EXT	GLOW	GLOW	GLOW	FLAME	EXT	GLOW	EXT	EXT	EXT
END OF TEST STATUS - IGNITERS	-	-	-	-	-	-	-	-	-	GLOW	GLOW	GLOW
REMARKS	FUEL 28.5 IN HIGH			OXYGEN 6-45=18% 46-00=16 PMAX=.5IN	OXYGEN 15-00=17% PMAX=.5IN	OXYGEN 44-00= 15.5% PMAX=.5IN				IN BOTH OF THESE TESTS WATER WAS ADMITTED TO OPEN SPRINKLERS AT THE TIME OF DETECTOR OPERATION		

NOTE - ALL TIMES IN MIN-SEC

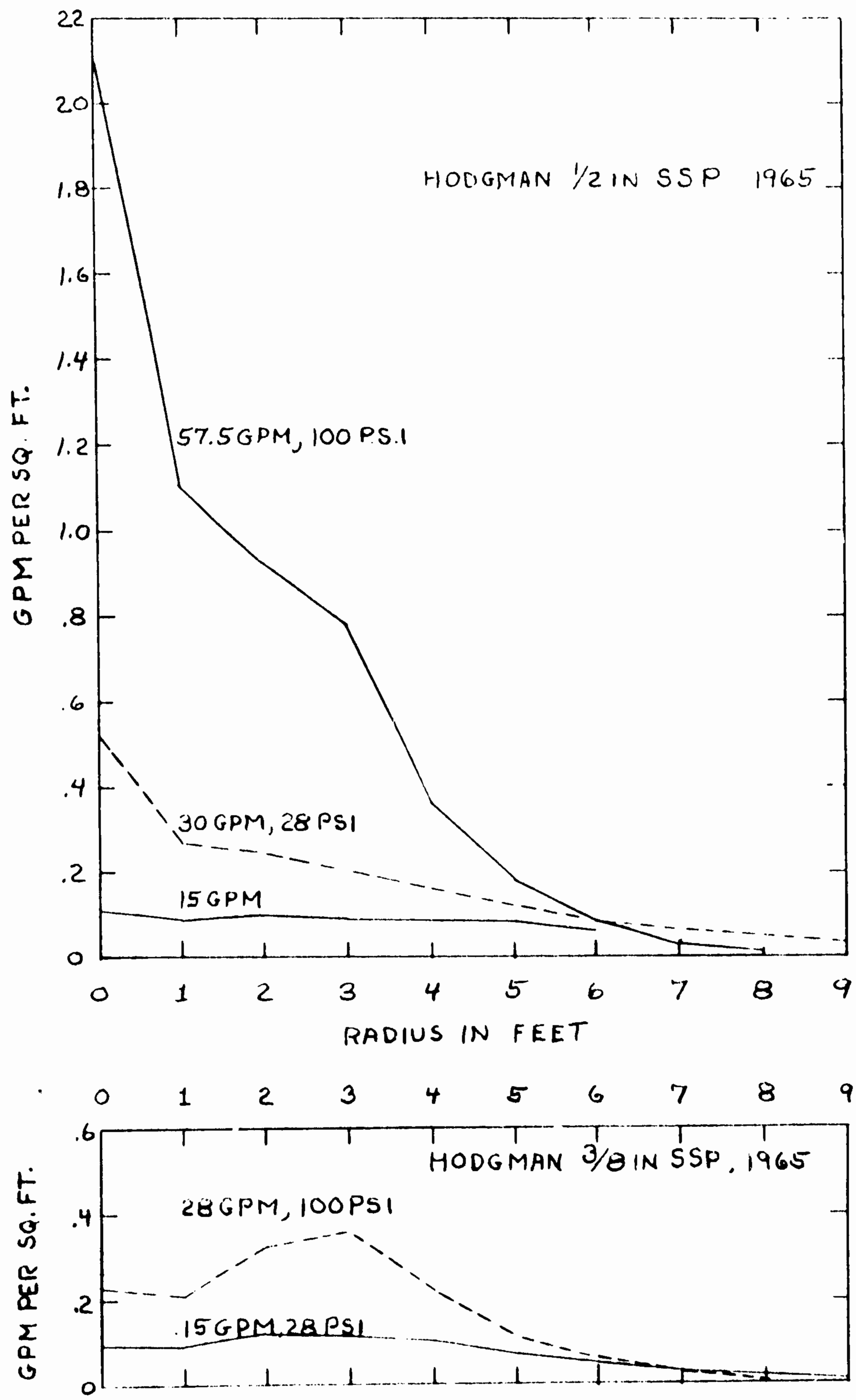

FRICTION LOSS THROUGH WATER
SYSTEM - INCLUDING 4 PSI ELEVATION
Flow - Gal. per Min.
N 1.85
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
Pressure - Lb. per Sq. In.
0 10 20 30 40 50 60 70 80 90 100 110 120



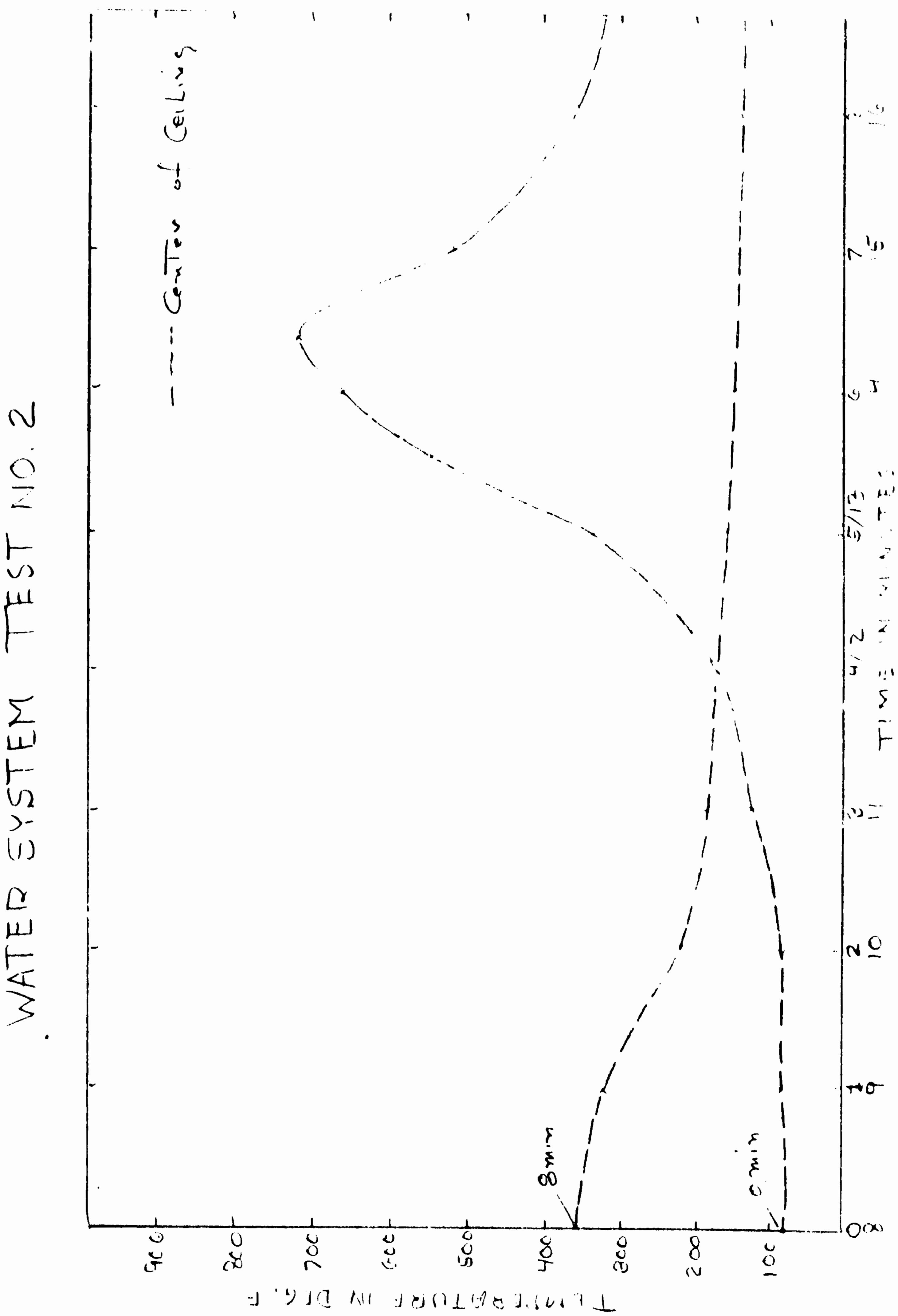
CALIBRATION - FLOW VS PRESSURE

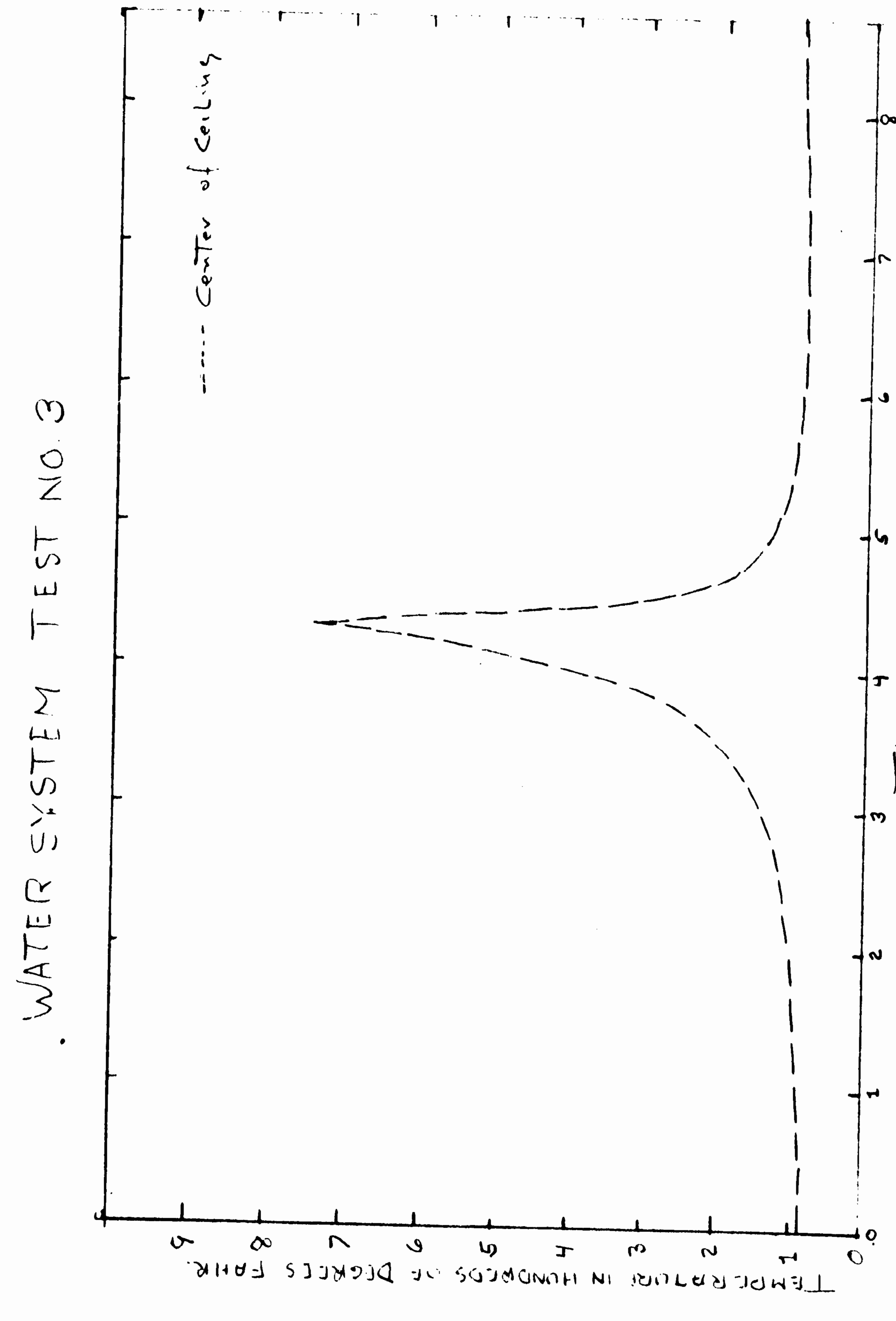
FOR TEST SPRINKLERS

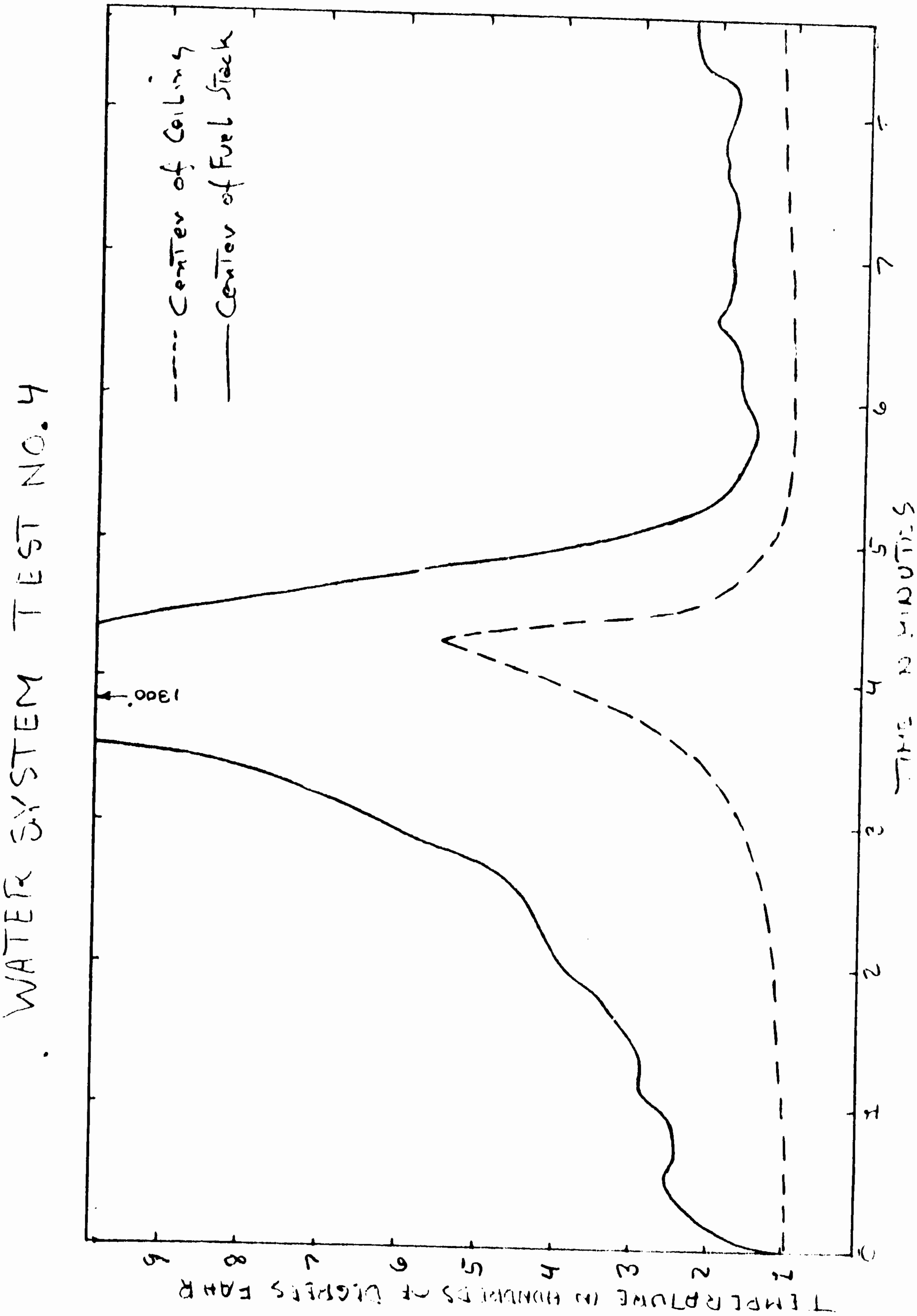
COMPARISON OF WATER DISTRIBUTION 4 FT BELOW DEFLECTORS OF THE TEST SPRINKLERS



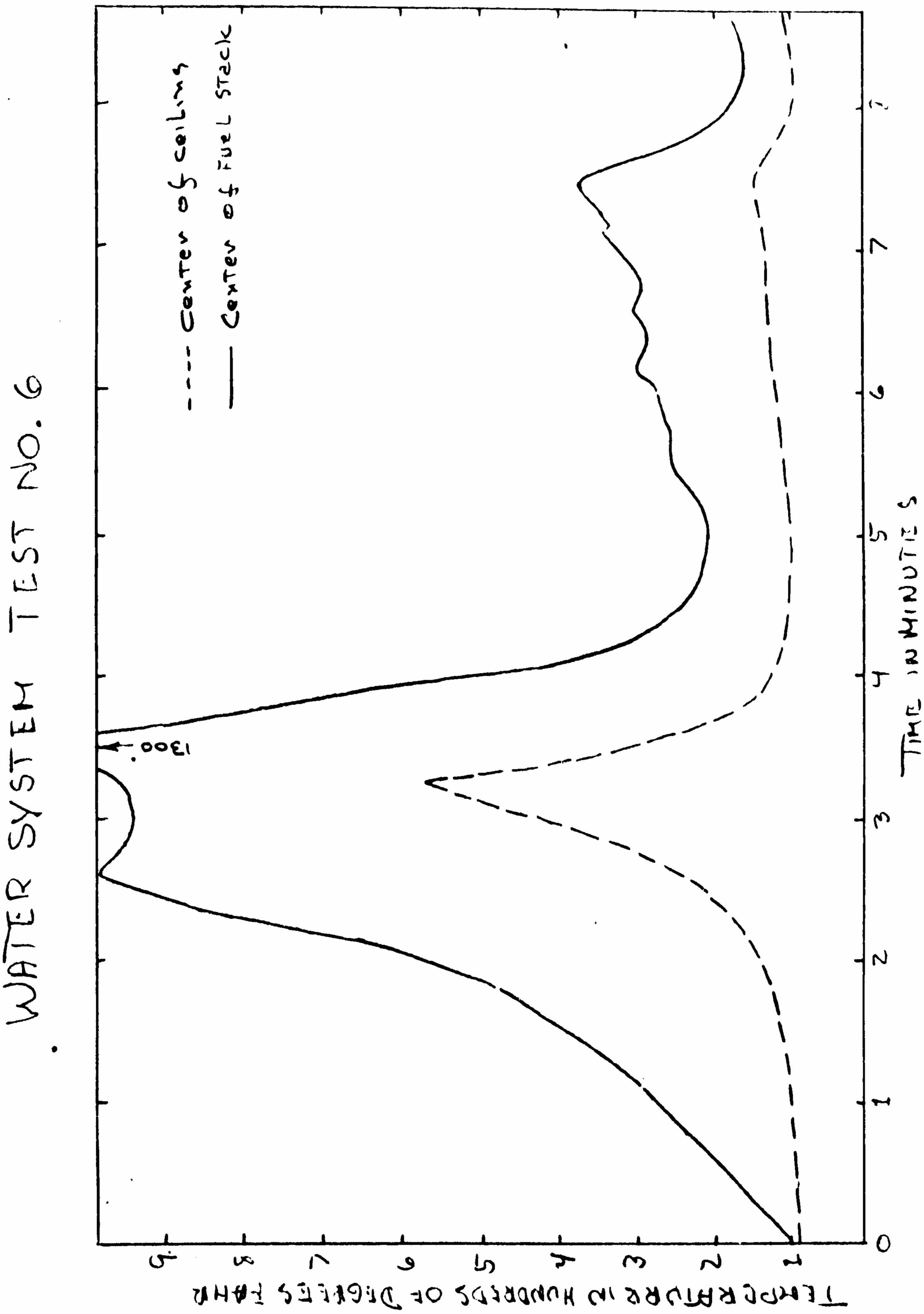
I 19974 APPENDIX B-5

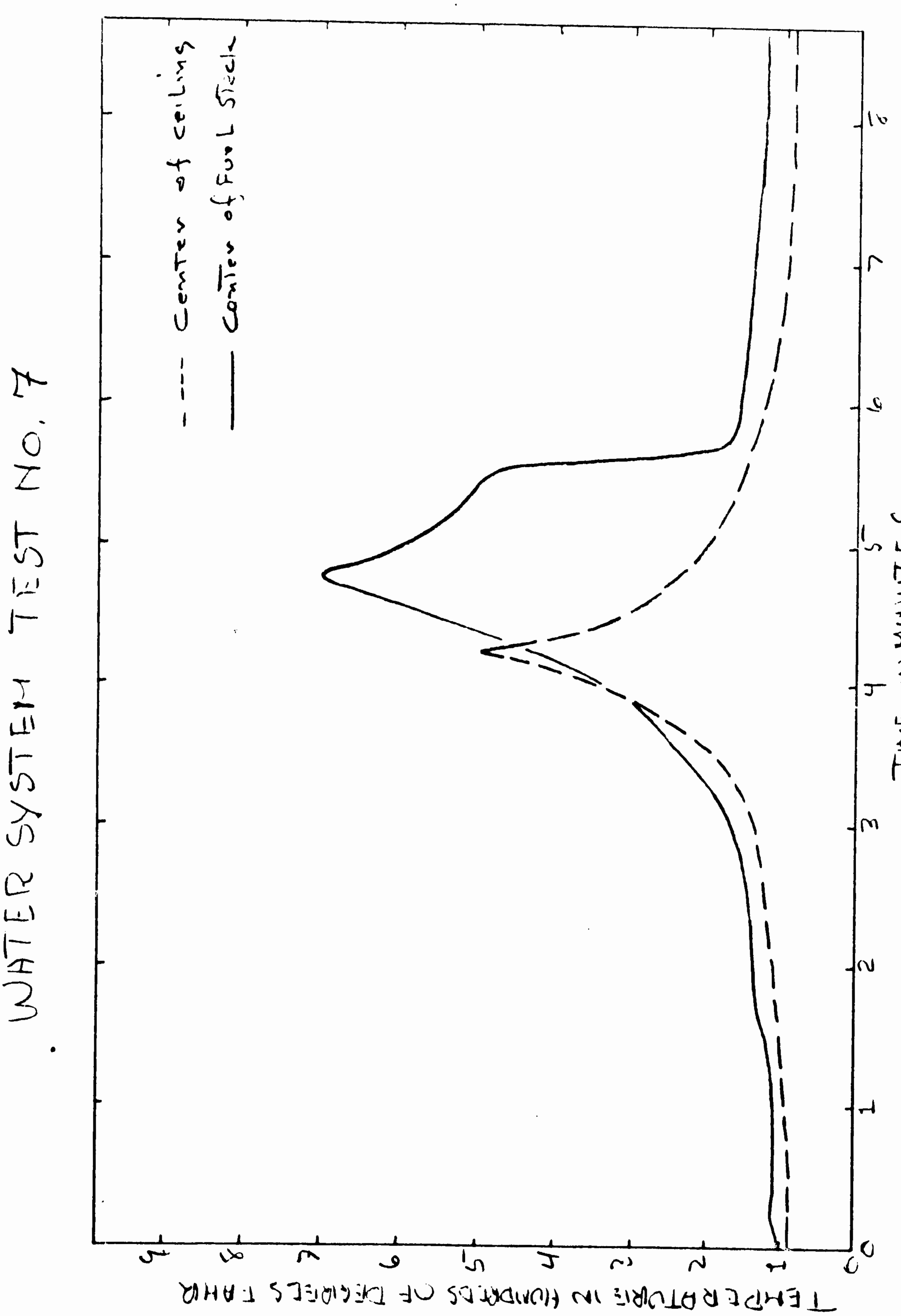


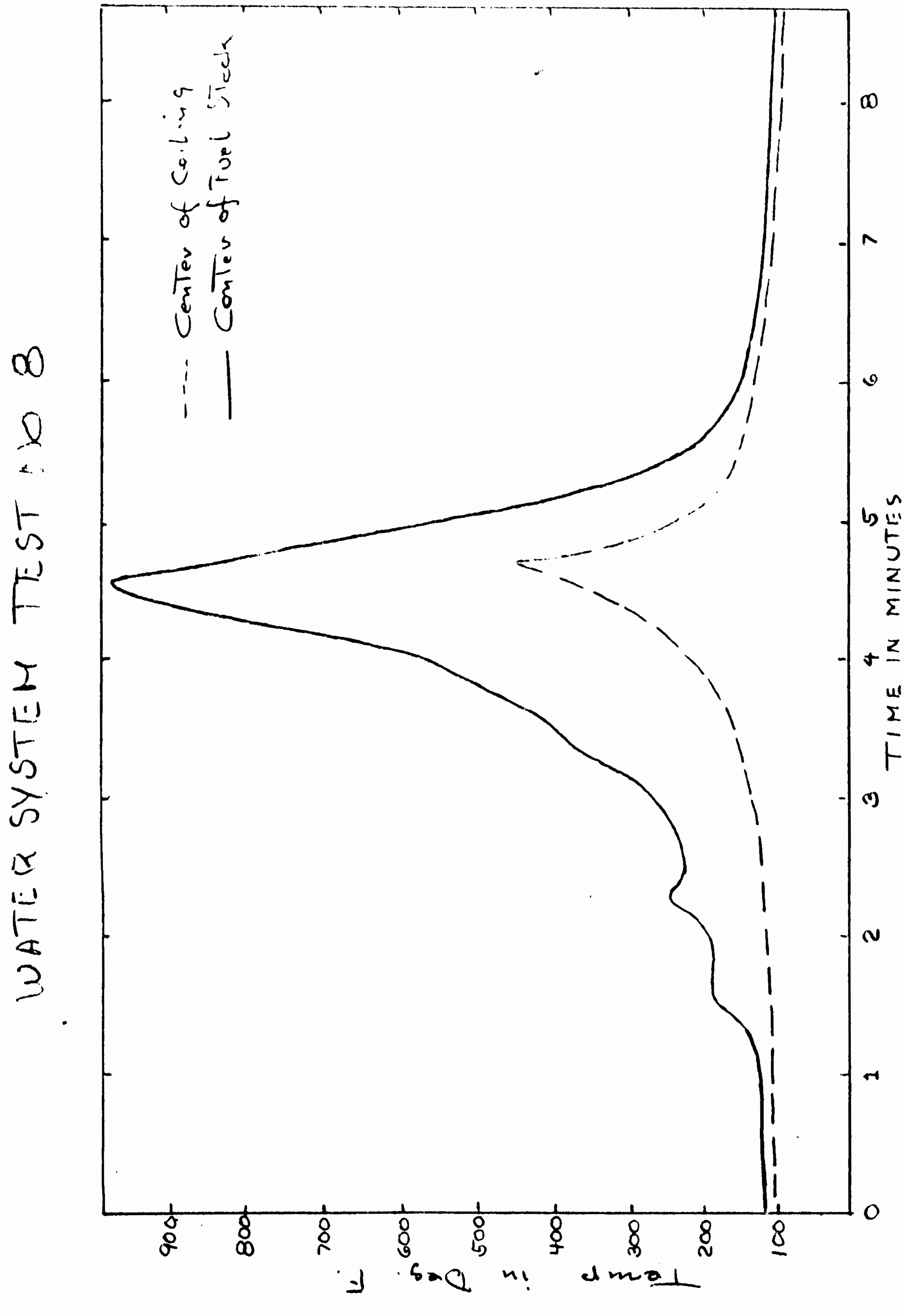

WATER SYSTEM TEST NO. 3
---- Center of Ceiling
TIME IN MINUTES
0 1 2 3 4 5 6 7 8
TEMPERATURE IN HUNDREDS OF DEGREES FAHR.
0 1 2 3 4 5 6 7 8 9

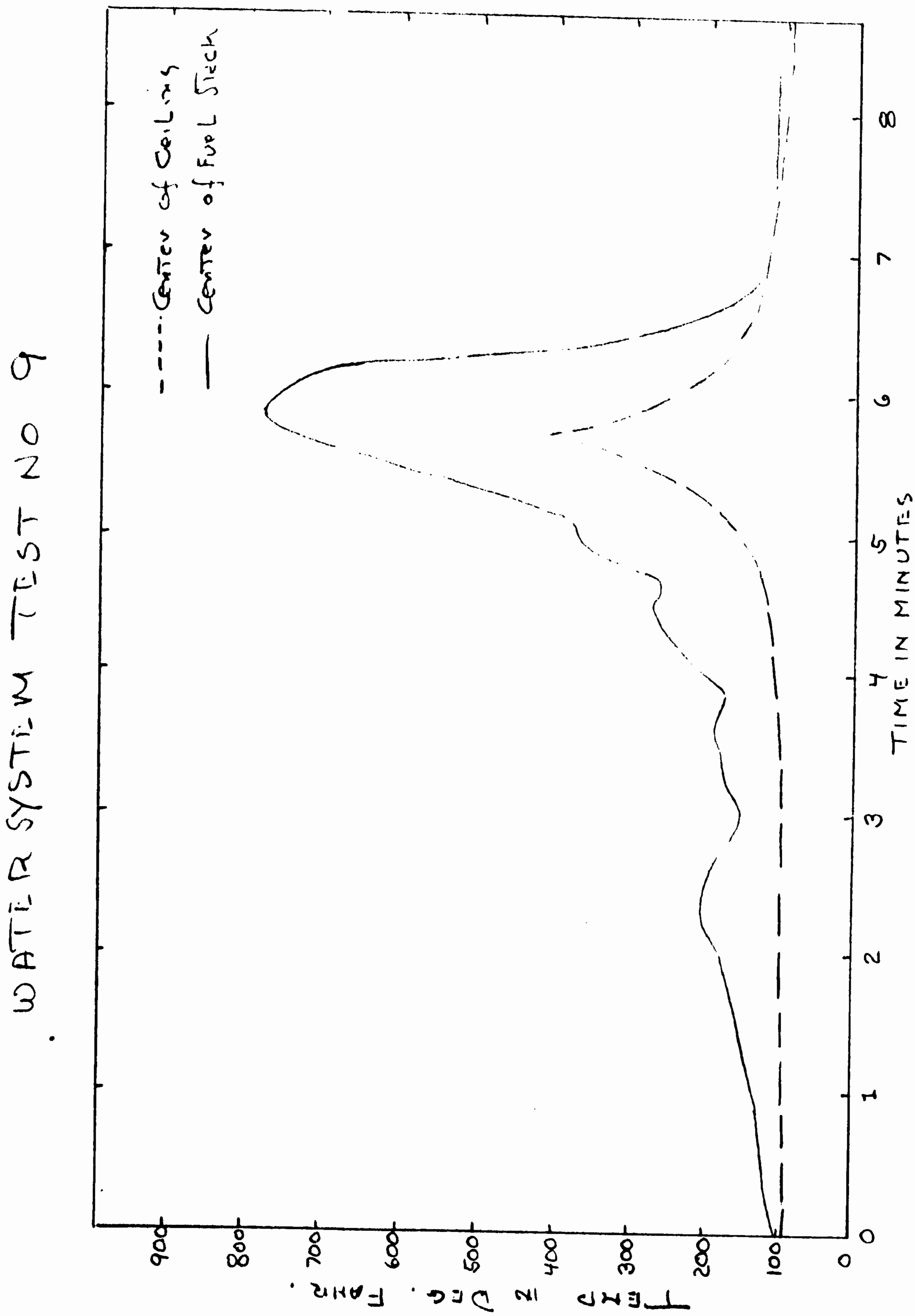

WATER SYSTEM TEST NO. 4
---- Center of Ceiling
—— Center of Fuel Stack
1300°
TIME IN MINUTES
TEMPERATURE IN HUNDREDS OF DEGREES FAHR
1
2
3
4
5
6
7
8
9


WATER SYSTEM TEST NO. 5
Center of Ceiling
Center of Fuel Stack
1230
TIME IN MINUTES
TEMPERATURE IN HUNDREDS OF DEGREES FAHR.
0 1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8 9


WATER SYSTEM TEST NO. 6
Center of ceiling
Center of Fuel Stack
1300°
TIME IN MINUTES
TEMPERATURE IN HUNDREDS OF DEGREES FAHR
0
1
2
3
4
5
6
7
8
9


WATER SYSTEM TEST NO. 7
Center of ceiling
Center of Fuel Stack
TIME IN MINUTES
TEMPERATURE IN HUNDREDS OF DEGREES FAHR


WATER SYSTEM TEST NO 8
--- Center of Ceiling
— Center of Fuel Stack
TIME IN MINUTES
0
1
2
3
4
5
6
7
8
Temp in Deg. F.
100
200
300
400
500
600
700
800
900


WATER SYSTEM TEST NO 9
Center of Ceiling
Center of Fuel Stack
TIME IN MINUTES
0
1
2
3
4
5
6
7
8
TEMP IN DEG. FAHR.
0
100
200
300
400
500
600
700
800
900

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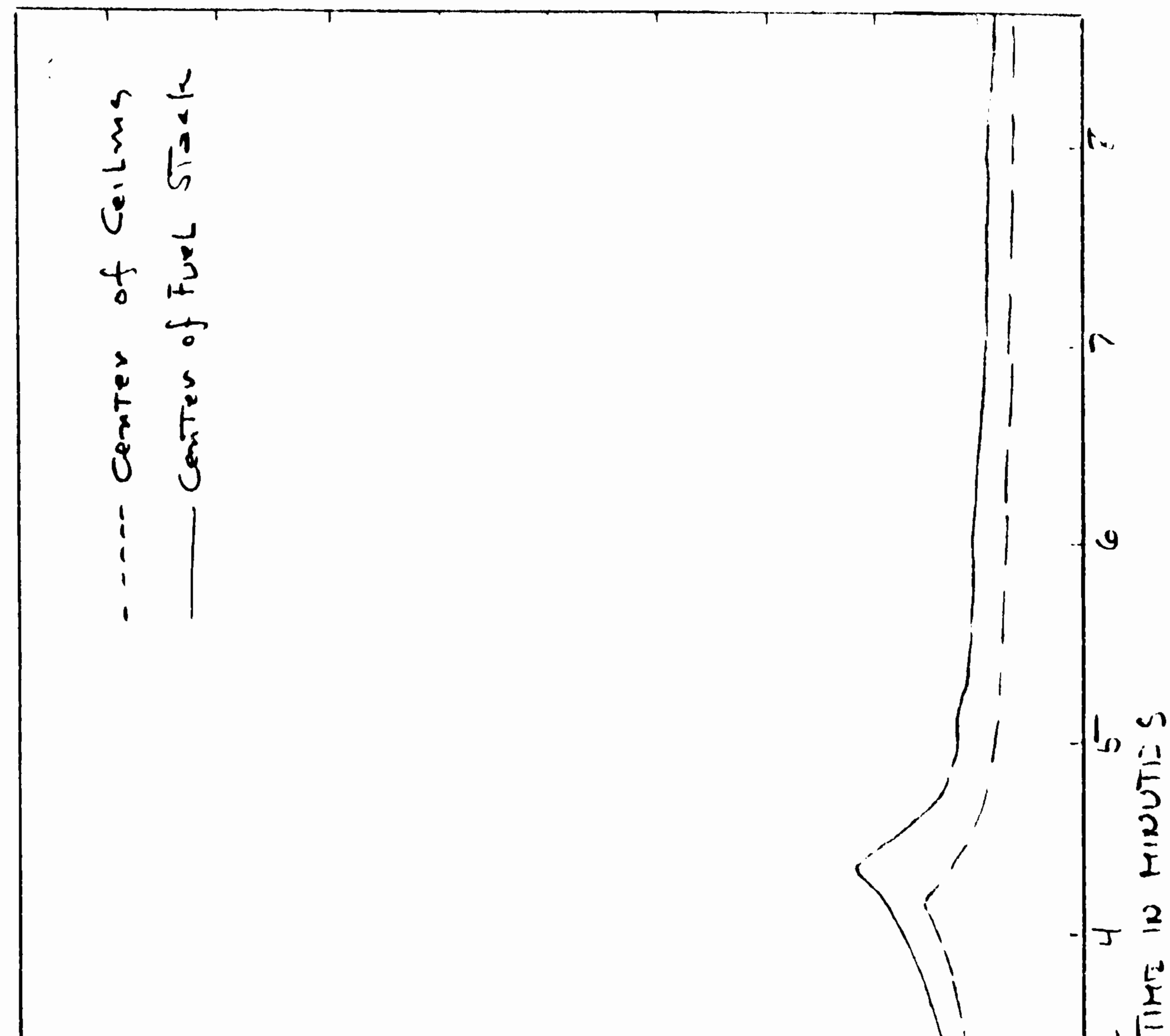
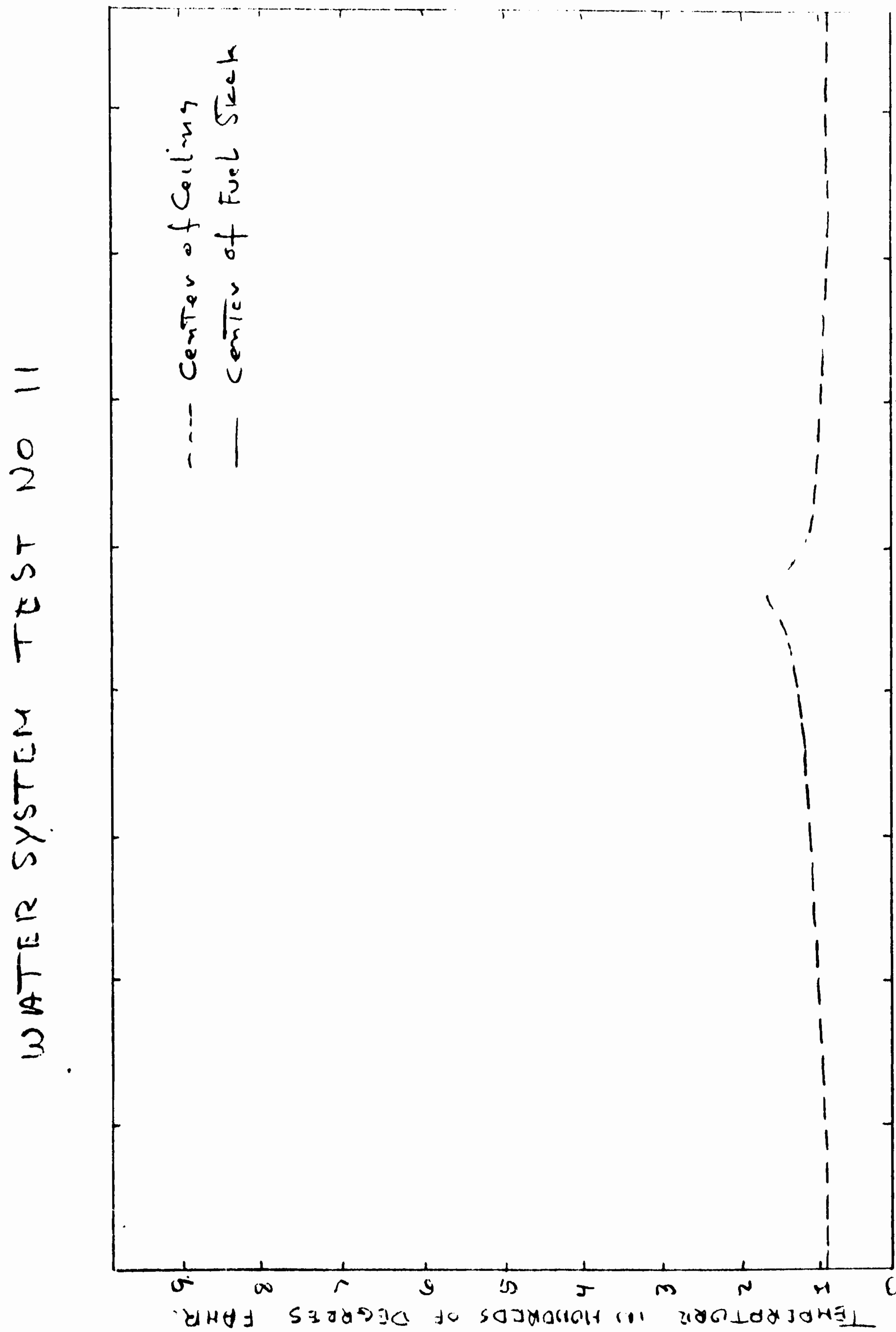
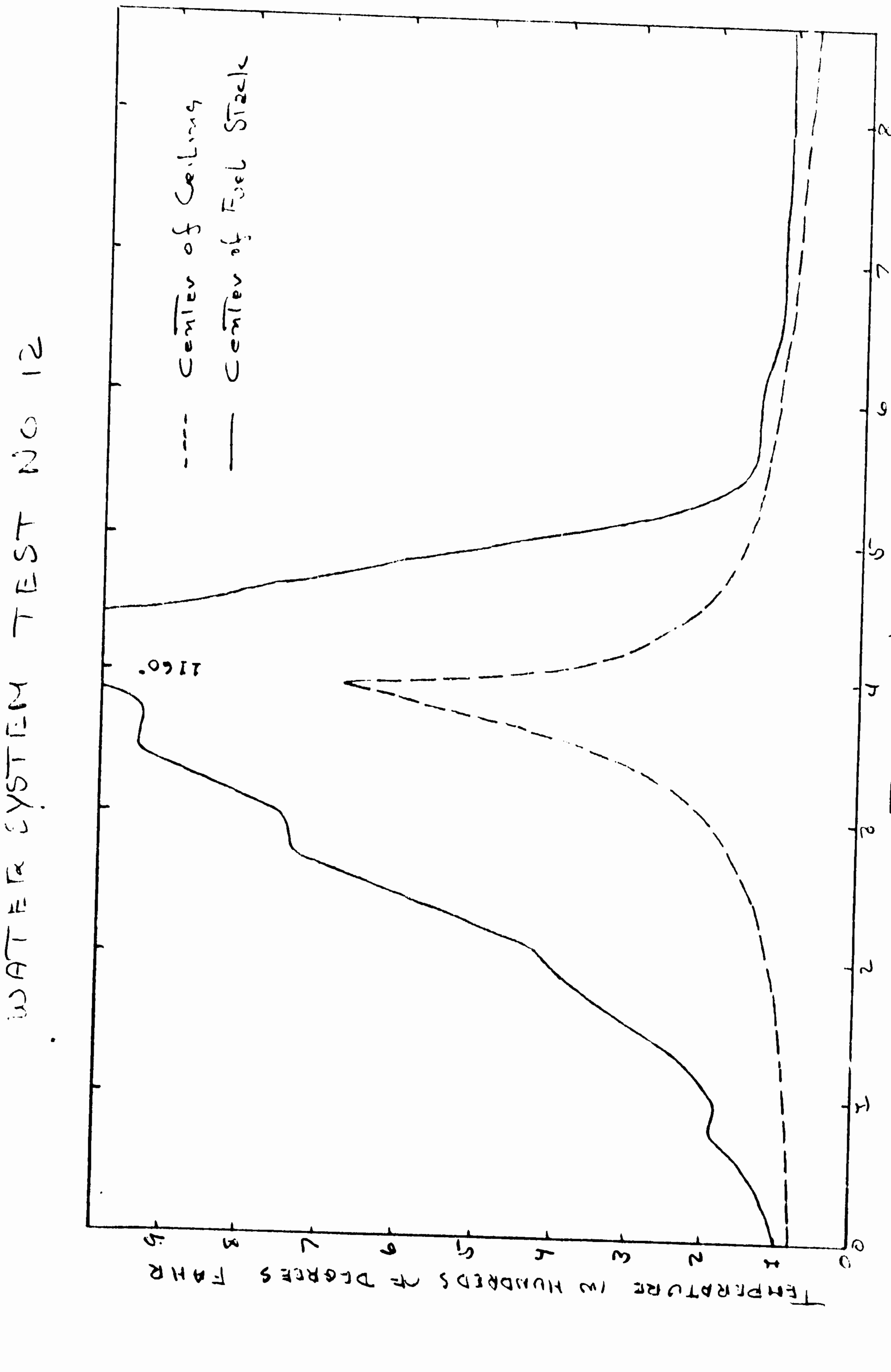
APPENDIX B-13

WATER SYSTEM TEST NO 10




WATER SYSTEM TEST NO 11
--- Center of Ceiling
— Center of Fuel Stack
TEMPERATURE IN HUNDREDS OF DEGREES FAHR.
0
1
2
3
4
5
6
7
8
9


WATER SYSTEM TEST NO 12
---- Center of Ceiling
—— Center of Fuel Stack
1160°
TIME IN MINUTES
TEMPERATURE IN HUNDREDS OF DEGREES FAHR
0
1
2
3
4
5
6
7
8
9

HALON-1301 SYSTEM TEST DATA

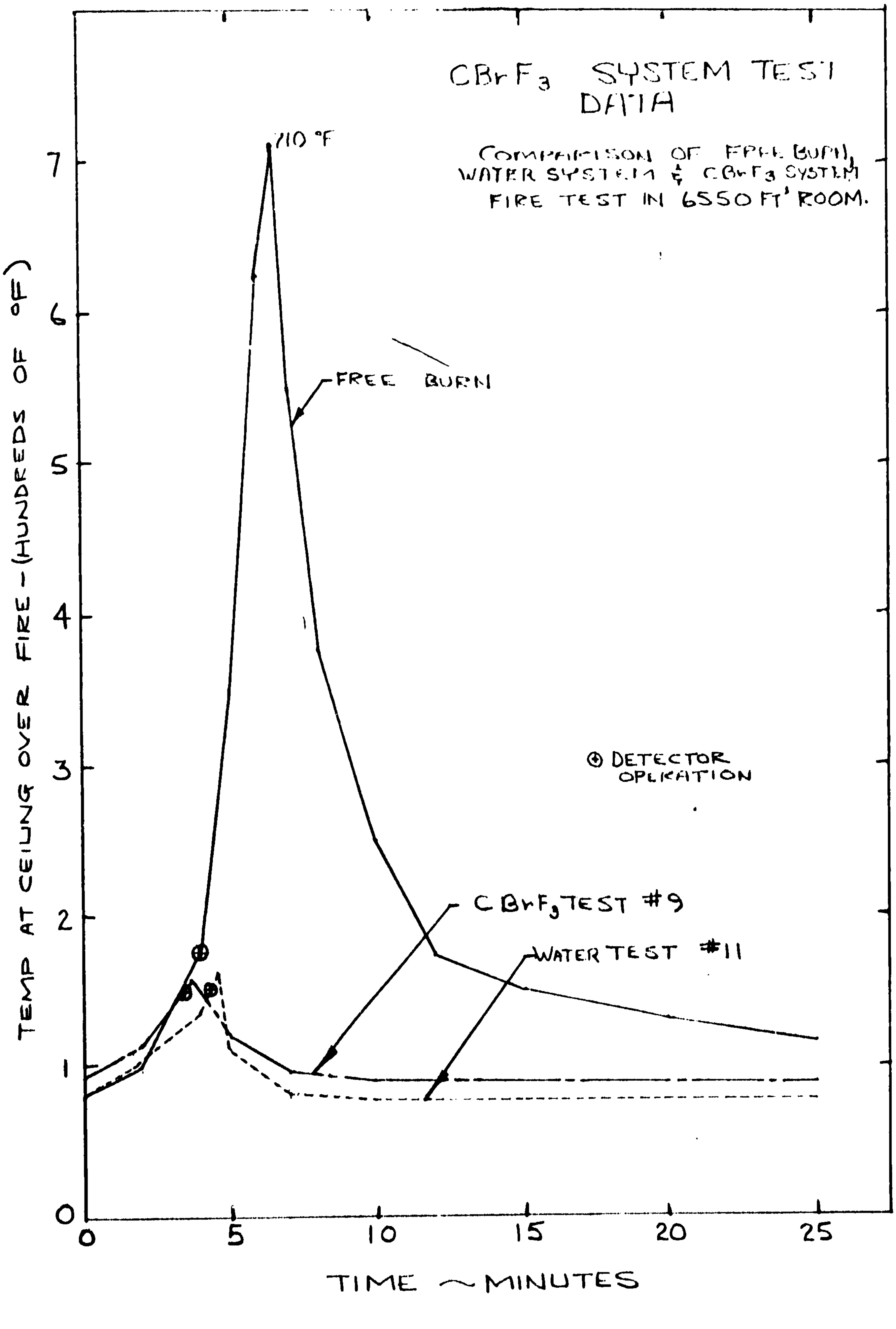
TEST NUMBER	1	2	3	4	5	6	7
DATE	9 Aug. 65	10 Aug. 65	10 Aug. 65	11 Aug. 65	11 Aug. 65	13 Aug. 65	13 Aug. 65
Temp, Humidity	73, 48	72, 55	72, 53	75, 53.5	75, 51.5	72, 48	72, 49
Volume (Ft^3)	180	180	180	180	180	180	180
Lbs. Agent Applied	Free Burn	Free Burn	5	5	3	3	3
Conc. (Vol%)	-	-	7.1%	7.1%	4.25%	4.25%	4.25%
Protected Vol/lb Agt.	-	-	36	36	60	60	60
Lbs. Wood or Cotton	2-1/8 wd.	2-3/16 wd.	2 wd.	2 wd.	2 wd.	2 wd.	None
Lbs. Paper Napkins	1/4	1/4	1/4	1/4	1/4	1/4	None
Total Wt. Loss	1-9/16	1-5/8	1/8	5/8	1/2	3/4	-
Wood Moisture (Ave.)	9%	6.5%	7%	7%	7%	6.5%	-
Detection Time	0:35	1:05	1:30	0:47	0:53	0:37	-
Agent Application Time	-	-	1:30	2:00	2:00	2:00	2:00
Delay	-	-	0	1 min.13 sec.	1 min.7 sec.	1 min.23 sec.	-
Discharge Duration	-	-	4.0 sec.+	11.25 sec.	6.5 sec.	6.2 sec.	4.7 sec.
Ave. Discharge Rate	-	-	48 lb/min.	27 lb/min.	28 lb/min.	29 lb/min.	38 lb/min.
Ventilation (cfm)	1	1	1	1	1	40	1
Po (psi)	-	-	222	222	219	222	222
P(flow) (psi)	-	-	-	-	210	212	-
Maximum Temp. (°F)	420 ceiling	1600 stk.	250 stk.	1290 stk.	670 stk.	1360 stk.	-
Length of Test	30 min.	30 min.	30 min.	30 min.	30 min.	15 min.	46 min.
Remarks:			Total Exting.	Total Exting.	Total Exting. Litmus Paper indicated some acid build-up in test volume.	Total Exting. Litmus Paper indicated acid build-up in test volume fire out within 10 sec.	

HALON-1301 SYSTEM TEST DATA

TEST NUMBER	8	9	10	11	12	13	14
DATE	16 Aug. 65	18 Aug. 65	24 Aug. 65	30 Aug. 65	30 Aug. 65	30 Aug. 65	30 Aug. 65
Temp, Humidity	75, 51	85, 84	74, 86	72, 44	72, 43	72, 41	72, 41
Volume (Ft^3)	180	6550	6550	180	180	180	180
Lbs. Agent Applied	2.5	77	74	4	2	2	2.5
Conc. (Vol%)	3.54%	3.0%	3%	5.7%	2.9%	2.9%	3.54%
Protected Vol/Lb Agt.	72	85	85	45	90	90	72
Lbs. Wood or Cotton	1-15/16 wd.	747 wd.	734 wd.	2 wd.	2 wd.	2 wd.	2 wd.
Lbs. Paper Napkins	1/4	None	None	1/4	1/4	1/4	1/4
Total Wt. Loss	3/4	0	6	5/8	5/8	13/16	7/8
Wood Moisture (Ave.)	6.0%	5/8%	7.0%	4.0%	4.0%	4.0%	4.0%
Detection Time	0:31	3:36	4:32	0:32	0:27	0:30	0:28
Agent Application Time	2:00	3:36	4:32	2:00	2:00	2:00	2:00
Delay	1 min.29 sec.	0	0	1 min.28 sec.	1 min.33 sec.	1 min.30 sec.	1 min.32 sec.
Discharge Duration	4.8 sec.	3 min.37 sec.	6 min.9 sec.	-	10 sec.	-	13 sec.
Ave. Discharge Rate	31 lb/min.	22 lb/min.	12 lb/min.	-	12 lb/min.	-	11.5 lb/min.
Ventilation (cfm)	40	None	None	1	40	60	60
Po (psi)	222	210	175	200	200	200	200
P(flow) (psi)	213	55 to 44	60 to 0		190	190	190
Maximum Temp. (°F)	1170 stk.	160 ceiling	150 ceiling	790 stk.	715 stk.	1010 stk.	990 stk.
Length of Test	30 min.	60 min.	60 min.	15 min.	15 min.	15 min.	15 min.
Remarks:	Total Exting. Litmus Paper indicated acid build-up before application of Freon. Possible carbonic acid.	Std. Igniters Placed at 3-1/2', 7', 10-1/2' and 14' Elevations extinguished. Re-ignited when subjected to 15 mph wind. Pallets completely exting.	150 lb.cyl. Discharged completely. Std. igniter Reacted same as Test #10 Pallets completely exting.	Sm. fan used to mix gas. wd. stk. Raised to 29" above floor to test vol. Total exting. Cold to the touch at 30 min.	Sm. fan used to mix gas. wd. stk. Raised to 29" above floor of test vol. Total exting. Warm to the touch at 20 min.	Wd. Stk. Raised to 29" above floor. Total exting. Warm to the touch at 20 min.	Wd. Stk. Raised to 29" above floor. Total exting. Warm to the touch at 15 min.

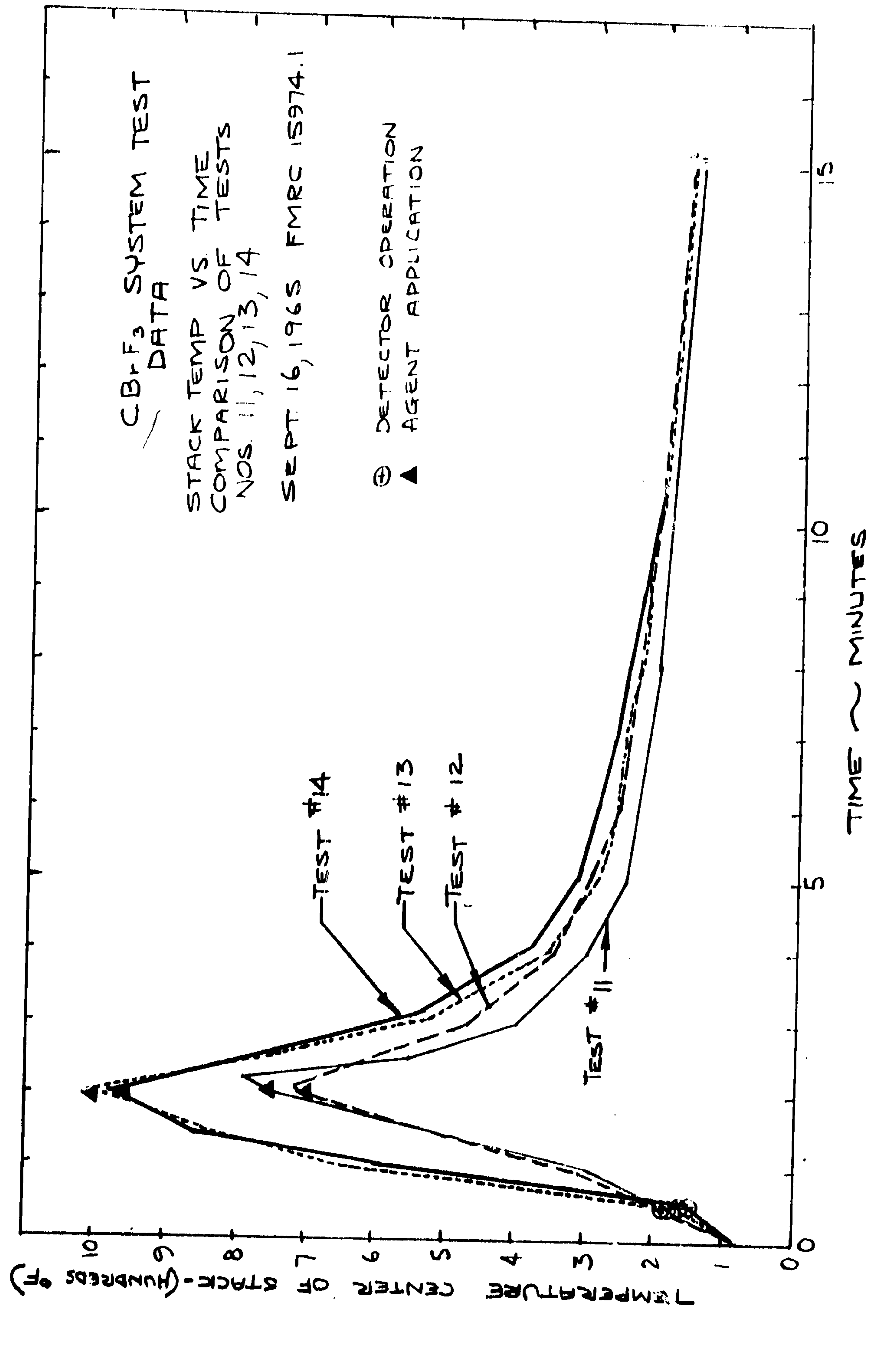
HALON-1301 SYSTEM TEST DATA

TEST NUMBER	15	16	17	18	19
DATE	30 Aug. 65	30 Aug. 65	2 Sept. 65	2 Sept. 65	2 Sept. 65
Temp, Humidity	72, 41	72, 41	72, 57	73, 52	72, 50
Volume (Ft^3)	180	180	180	180	180
Lbs. Agent Applied	2.5	2.0	Free Burn	3.5	3.5
Conc. (Vol%)	3.54%	3.9%	-	5.0%	5.0%
Protected Vol/Lb Agt.	72	90	-	50	50
Lbs. Wood or Cotton	3/16+	3/16+	1/4	3/16+	1/4
Lbs. Paper Napkins	1/4	1/4	1/4	1/4	1/4
Total Wt. Loss	7/16	7/16	7/16+	1/4+	5/8-
Wood Moisture (Ave.)	-	-	-	-	-
Detection Time	0:35	0:33	0:30	0:36	0:48
Agent Application Time	3:00	3:00	-	1:00	1:00
Delay	2 min.25 sec.	2 min.27 sec.	-	24 sec.	12 sec.
Discharge Duration	-	-	-	-	-
Ave. Discharge Rate	-	-	-	-	-
Ventilation (cfm)	60	None	None	0 to 15 min. 0 15 to 60 min. 60	None
Po (psi)	200	200	-	210	210
P(flow) (psi)	190	190	-	-	-
Maximum Temp. (°F)	1180 wads.	1590 wads.	1575 wads.	1650 wads.	1720 wads.
Length of Test	15 min.	22 min.	30 min.	60 min.	60 min.
Remarks:	90% Consumed Smoldering Still visible at end of test. Fuel: two cotton wads.	90% Consumed Smoldering Still visible at end of test. Sm. fan used to mix gas. Fuel: two cotton wads.	Wads 95% Consumed Outer layer of cotton preserved. Core burned out. Fuel: two cotton wads.	Left wad 95% consumed, warm to the touch. Right wad not seriously damaged. Exting. completely. Some paper re- mained undamaged. Fuel: two cotton wads.	Right wad 95% consumed. Left wad not seriously damaged, exting. completely. 1 oz. paper remained. Fuel: two cotton wads.


$CBrF_3$ SYSTEM TEST DATA
COMPARISON OF FREE BURN, WATER SYSTEM & $CBrF_3$ SYSTEM FIRE TEST IN 6550 FT³ ROOM.
710 °F
FREE BURN
⊕ DETECTOR OPERATION
$CBrF_3$ TEST #9
WATER TEST #11
TEMP AT CEILING OVER FIRE - (HUNDREDS OF °F)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
TIME ~ MINUTES

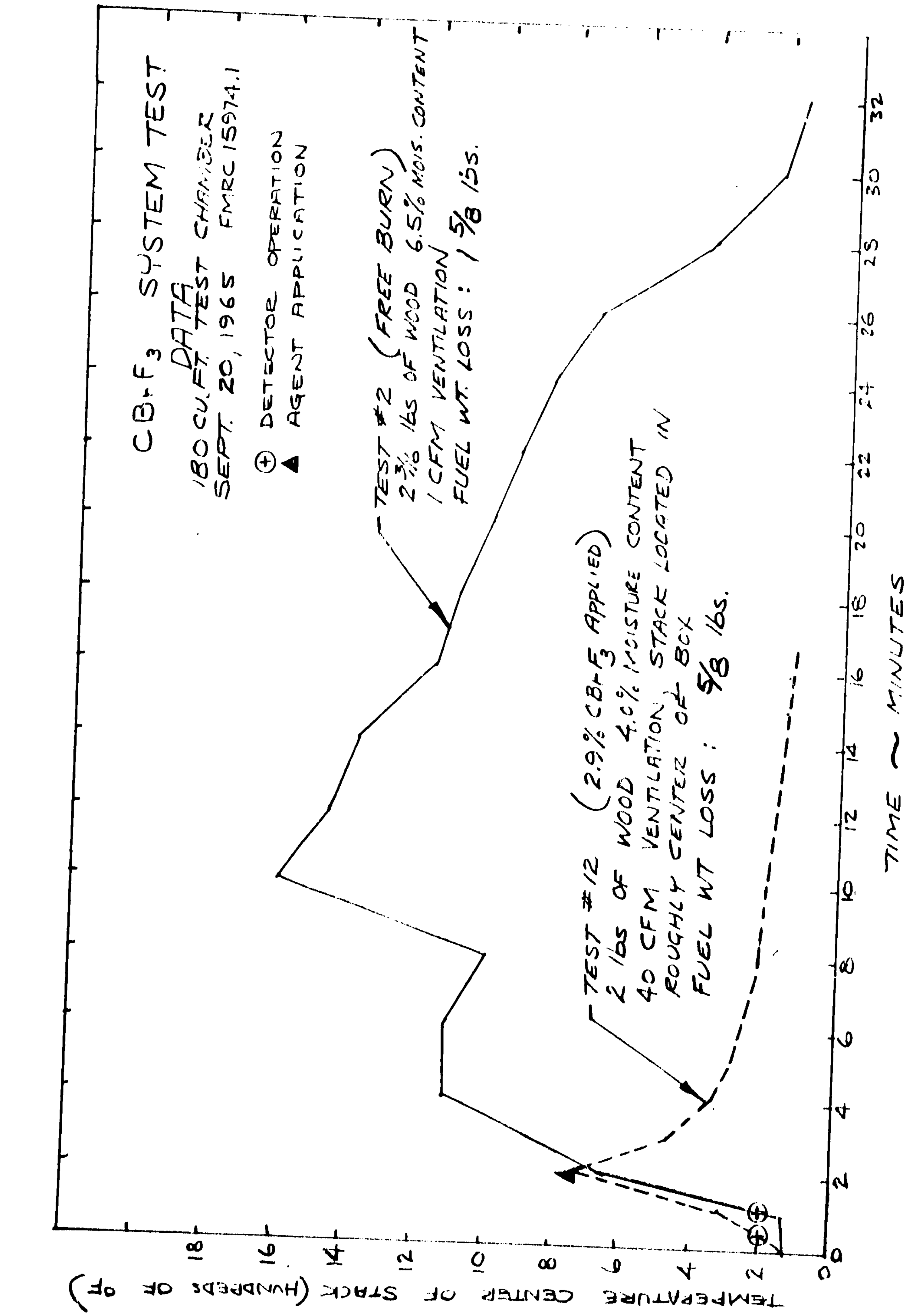
15974.1

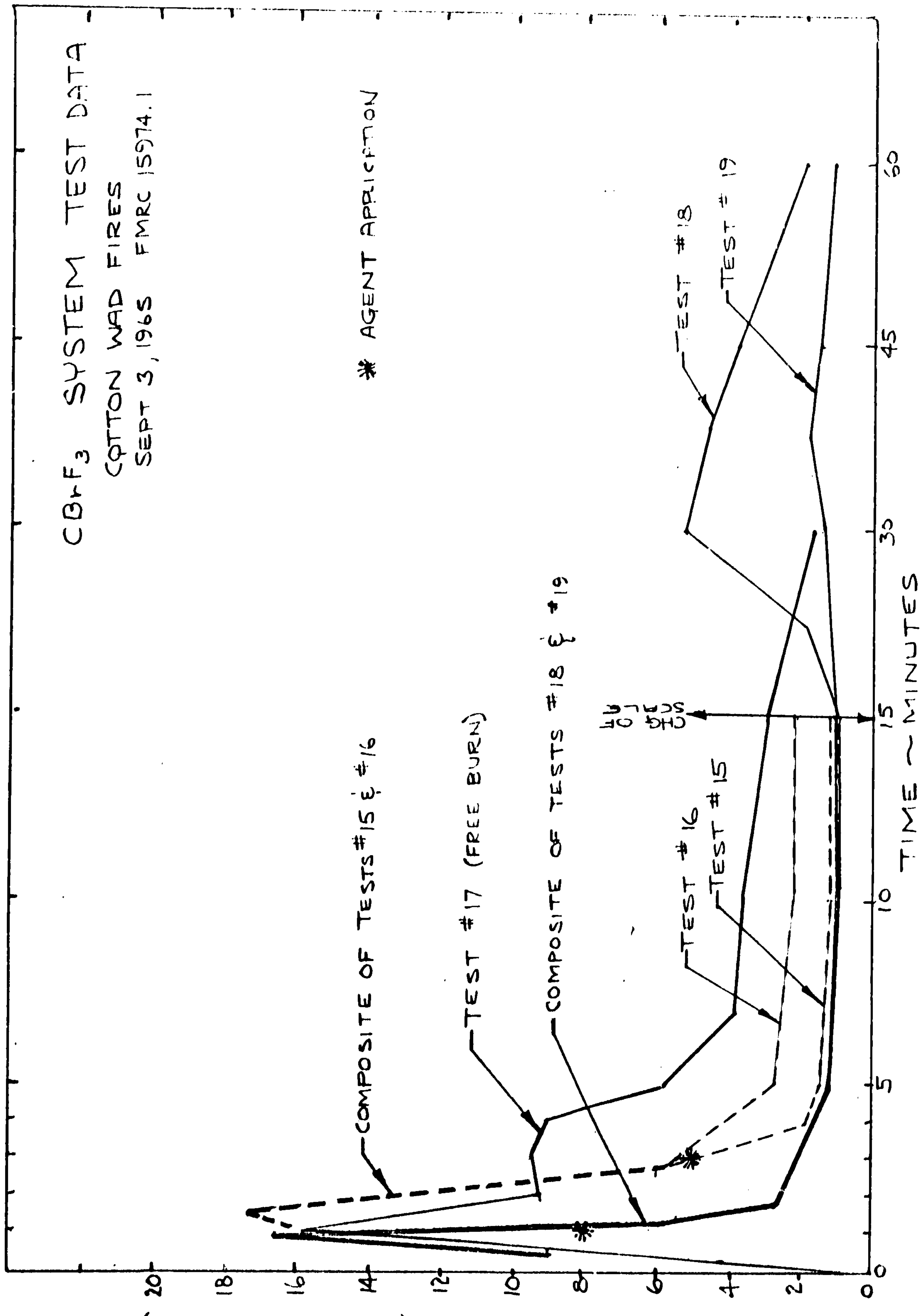
APPENDIX

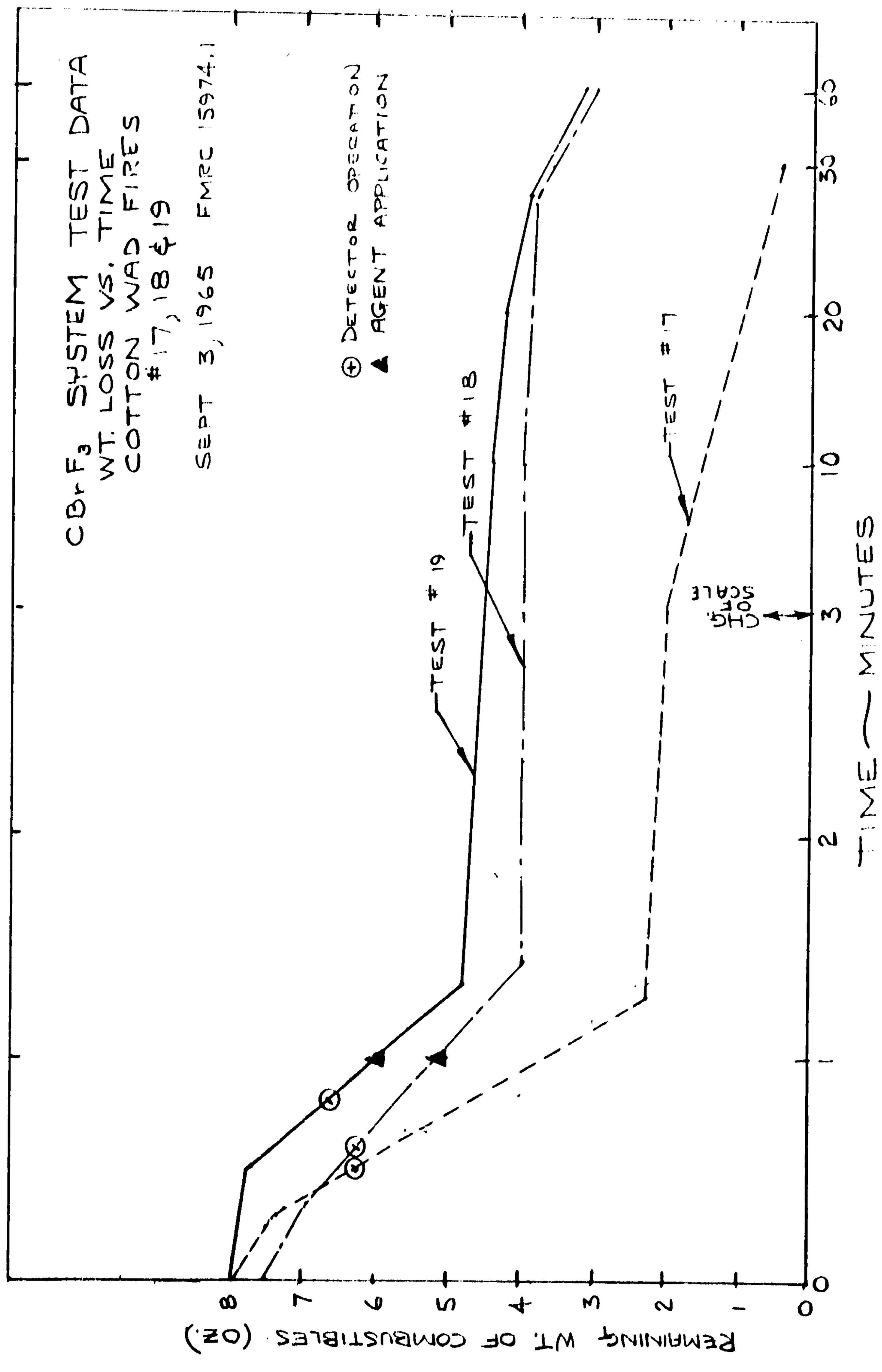


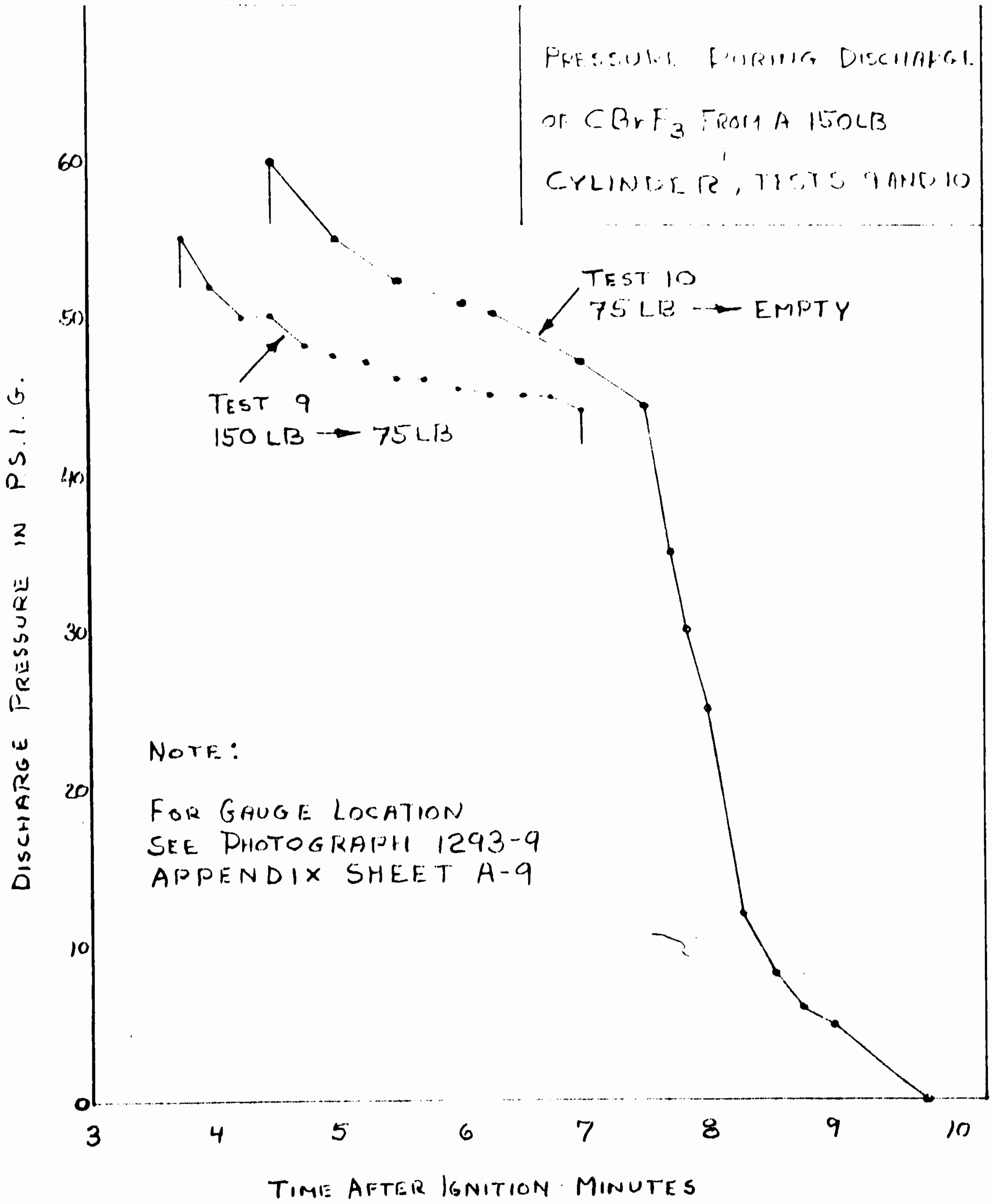
15974.1

APPENDIX C-6

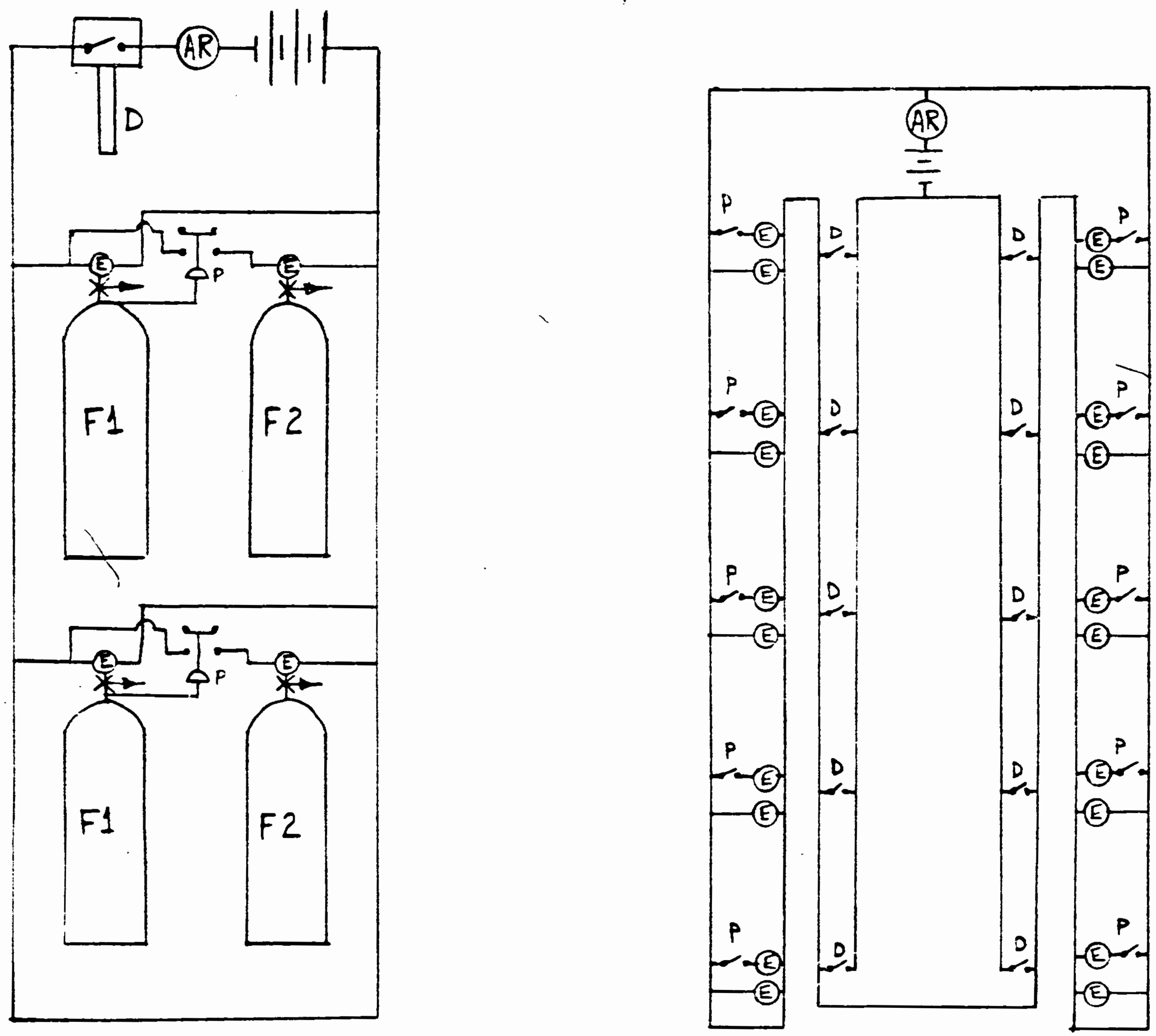



CBrF3 SYSTEM TEST DATA
COTTON WAD FIRES
SEPT 3, 1965 FMRC 15974.1
* AGENT APPLICATION
TEST #18
TEST #19
COMPOSITE OF TESTS #15 & #16
TEST #17 (FREE BURN)
COMPOSITE OF TESTS #18 & #19
TEST #16
TEST #15
CHG OF SCALE
TIME ~ MINUTES
0
5
10
15
30
45
60
COTTON WAD TEMP (HUNDREDS OF °F)
0
2
4
6
8
10
12
14
16
18
20


$CBrF_3$ SYSTEM TEST DATA
WT. LOSS VS. TIME
COTTON WAD FIRES
#17, 18 & 19
SEPT 3, 1965 FMRC 15974.1
DETECTOR OPERATION
AGENT APPLICATION
TEST #19
TEST #18
TEST #17
CHG. OF SCALE
TIME — MINUTES
REMAINING WT. OF COMBUSTIBLES (OZ.)


PRESSURE DURING DISCHARGE
OF $CBrF_3$ FROM A 150LB
CYLINDER, TESTS 9 AND 10
TEST 10
75 LB → EMPTY
TEST 9
150 LB → 75 LB
NOTE:
FOR GAUGE LOCATION
SEE PHOTOGRAPH 1293-9
APPENDIX SHEET A-9
DISCHARGE PRESSURE IN P.S.I.G.
TIME AFTER IGNITION MINUTES
60
50
40
30
20
10
0
3
4
5
6
7
8
9
10

SCHEMATIC LAYOUT OF A $CBrF_3$ SYSTEM FOR 40'x100' BLDG.



Ⓔ - EXPLOSIVE ACTIVATED VALVE

P - PRESSURE SWITCH

→ - NOZZLE, See Appendix Sl.Ts A-1, A-5

D - FIRE DETECTOR

(AR) ALARM RELAY

SPECIFICATIONS

1. CYLINDER - Volume: 1.333 cu. ft. (100 pounds $CBrF_3$ at 75 lb/cu. ft. filling density)

   Suggested material: steel

   Working pressure: 1500 psi at 140°F

   Test pressure: 2200 psi at 150°F

   Pressure relief at 1600 psi through relief valve or bursting disc assembly

   Construct and label in accordance with Interstate Commerce Commission Regulations

   Liquid discharge should be through dip tube assembly

   Total pressure of cylinder at 70°F after pressurization with nitrogen to be 770 psi

2. BATTERY - Nickel - Cadmium, 12 volt, 100 amp - hour rating. Cold climate rating (-65°F)

3. PRESSURE SWITCH - Electrical rating: 12 volt d-c

   Pressure to which control may be subjected without appreciably affecting performance: 1500 psi

   Normally open contacts when under positive pressure

   When positive pressure drops below 10 psi electrical contact should close

   Possible material: Stainless Steel Bellows, Cast Brass Body

   Suitable current ambient temperature range of -65°F to +140°F

4. EXPLOSIVELY OPERATED VALVE WITH ELECTRIC PLUG - Similar to those used in standard fixed CO_2 systems. To be mounted on cylinder head.

   Suitable for an ambient temperature range of -65°F to +140°F

   Electric plug should operate with d-c supply

5. DETECTOR - Thermal switch capable of withstanding momentary over-shoot of 2000°F at the probe and 800-1000°F at the body. Sensitivity within ±1°F, 12 volt d-c, 2 amp, set point to be 140°F for normal temperate zone application. Set point at least 20°F in excess of maximum expected temperature in other areas.

6. FITTINGS - Wrought copper.

7. CABLE - Copper clad, mineral insulated, two conductor, #16 wire, cable.

8. NOZZLE ASSEMBLY - See sketch in Appendix. Nozzle consisting of four 1/8 in. horizontal jets and four 1/8 in. vertical jets is suggested.

9. HALON 1301 - ($CBrF_3$) Bromotrifluoromethane.

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3. REPORT TITLE Fire Tests of Two Remote Area Fire Suppression System Concepts	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report	
5. AUTHOR(S) (Last name, first name, initial) Smith, J. B., Miller, M. J., and Pote, R. L., Jr.	

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO OF REFS
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13. ABSTRACT

Two packaged, self-contained fire suppression systems were fire tested to determine which would best meet the remote area fire protection needs. Results of 31 tests indicate that the multi-cycle, total flooding system using Bromotrifluoromethane is superior to the automated sprinkler system using water.

DD FORM 1 JAN 64 1473

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Fire Extinguishers						
Fire Alarm Systems						
Fire Tests						

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